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NOTICES

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GROWTH OF PASTURE SPECIES

I. SHORT ROTATION AND PERENNIAL RYEGRASS

By K. J. MITCHELL, Grasslands Division, Department of Scientific and Industrial Research, Palmerston North

(Received for publication, 17 May 1954)

Summary

Young plants of two New Zealand strains of ryegrass, short-rotation and perennial, were grown under temperature conditions approximating those of a normal autumn and a warm summer in the Manawatu district. At each temperature level a group of plants was either allowed free growth, defoliated once or twice, or shaded.

The morphological examination of the pattern of development follows the procedure outlined in previous papers.

On the free growing plants, tillering, the appearance of successive leaves on a tiller, and the rate of formation of tissue on an individual tiller were generally faster at the summer temperature. However, the check to development caused by defoliation or by shading was relatively more severe at the higher temperature level.

In full light, undefoliated plants of both strains grew faster at the higher temperature. If plants were defoliated or shaded the difference in temperature levels had little effect on the rate of growth of either strain.

INTRODUCTION

The value of a detailed examination of the pattern of growth, and distribution of tissue formed in individual pasture plants lies in the assistance that this gives to a plant breeding programme and to an understanding of the growth of pasture associations in the field.

Although the rate of growth of a plant as a whole is of major importance, there are other aspects of growth which also assume importance where the plant is a component of a complex pasture association. For example, it often occurs that the individual tillers become the effective units of growth. Again, in a long pasture the length to which the leaves can grow may determine whether a plant survives.

In developing detailed studies of the influence of environmental conditions on the growth of pasture species it was considered essential to first examine in detail the influence of large differences in environmental conditions on the pattern of growth. This can be done by modifications of seasonal weather conditions, i.e. by shading or by use of a heated glasshouse. Subsequently the emphasis can be changed to precise measurement of the influence of relativly small, but known and controlled, differences in levels of light intensity and temperature on selected features of growth.

The work reported here belongs to the initial phase of the study and is primarily concerned with checking, and extending under New Zealand conditions, the results from earlier studies of ryegrass in Britain (Mitchell, 1953 a and b, 1954). Subsequent papers of this series will report extension to other species of grass and clover.

The literature has been reveiwed in the papers mentioned above.

EXPERIMENTAL METHODS

Seed of the two New Zealand strains of ryegrass, short-rotation and perennial was sown at the beginning of March in highly fertile potting soil in one-gallon glazed porcelain pots. Three days after seedling emergence plants were thinned to four per pot, with selection for uniformity of size. For each strain the pots were then randomly divided into two sets, one being placed in a heated glasshouse and the other in the open. The aim was to produce an approximation to the temperatures of a warm summer and a normal autumn in the Manawatu. A thermograph placed at each site indicated that mean temperatures during the experimental period were approximatly 72°F. and 57°F. respectively.

Measurements indicated that the glasshouse transmitted only 65% of daylight. To equalise the light intensity at the two temperature levels, all plants outside were grown under a single layer of butter-muslin. This gave the same reduction in light intensity as the glasshouse. For convenience, that level is termed "full light" in papers in this series.

Further treatments were imposed when the fourth leaf on the main stem had appeared on the majority of plants in each group. The exact time varied from 21 to 24 days after emergence, depending on strain, and on temperature levels.

These treatments were:—

(1) Continued free growth;

(2) Defoliation;

(3) Defoliation at the same time as Treatment 2, then again a week later;

(4) Shading.

For the shaded sub-groups two layers of scrim were used to cut off approximately 70% of the light being received by those sub-groups in "full light".

With the first defoliation the aim was to remove from the plants the same proportion of photosynthetic tissue irrespective of the differences in habit of growth induced by previous temperature levels. Plants at 57°F. were defoliated 1.25 in. above ground level and those at 72°F.

at 1.50 in. This treatment gave an initial reduction in the total quantity of photosynthetic tissue of the same order as the reduction in light intensity in the shading treatment, i.e. about 70%.

At the time when the final treatment differences were applied 16 plants from each main group were harvested. These gave an estimate of the mean weight of the plants at that time and of the proportion of tissue removed in the first defoliation. Final comparisons between treatments are based on sub-groups of 10 plants.

A surplus of seed was sown in each pot. This allowed selection for uniformity which was carried out just before the plants were transferred to the different levels of temperature, i.e. just prior to the appearance of the second leaf on the main stem. As a result of this rather early selection, individual plants in each sub-group later exhibited considerable variability both in form and rate of growth. Although this makes interpretation of results more difficult it is a reflection of the aims of the plant breeder who desires a clear distinction between strains but a measure of variability within each strain.

Observations on each plant were made during growth at frequent intervals, often daily. They included:

(a) Count of total number of tillers and, in the initial period, a record of time of appearance and position of every tiller on each plant;
(b) Number of leaves on main stem and on each tiller;
(c) Measurement of the rate of elongation of successive leaves on the main stem.

Plants in each sub-group were harvested when nearly all had eight leaves on the main stem. The length, median width, and green weight of each leaf on the main stem were measured. At the same time the plants were subdivided into first, second, and third order tillers and the green weight of these groups recorded. "Stems", i.e. the sheaths at the base of each leaf, were weighed separately. Each lot was then dried for 24 hr. at 105°c. and re-weighed.

Previous evidence (Mitchell, 1953a) shows a complex series of interactions between strain of plant, light intensity, temperature, and defoliation. The range of treatments used in this trial is not broad enough, nor is each individual treatment capable of sufficiently precise definition, for the exact pattern of these interactions to be elucidated. This does not prevent the recognition of general trends—the aim of this trial—but it does preclude any definition of their limits. Hence, detailed statistical analysis is not attempted. Where the data presented is appropriate, co-efficients of variation or standard deviations are stated. Conclusions drawn from comparisons between treatments are based primarily on these.

Results

Growth of the Whole Plant

The experiments were not designed to give accurate comparisons of rate of growth. They are concerned primarily with the manner in which the pattern of tissue formation can be modified. However, an estimate of the total quantity of shoot tissue formed in the 15 days after the commencement of each treatment can be calculated from the data (Table 1). As this is an integration of the effect on total growth of each of the features of morphological development which are examined, it provides a convenient starting point.

TABLE 1. INCREASES IN DRY WEIGHT OF PLANTS—ROOTS EXCLUDED
(mg. of dry matter)

Treatment	Initial Weight of Plant				Weight remaining after first defoliation				Estimated weight of tissue formed in 15-day period after treatment differences applied			
	Short Rotation		Perennial		Short Rotation		Perennial		Short Rotation		Perennial	
	57°F	72°F	57°F	72°F	57°F	72°F	57°F	72°F	57°F	72°F	57°F	72°F
Full Light	37.5	32.0	41.3	37.4					282	338	177	225
Defoliated Once	42.6	31.2	38.6	40.6	20.5	12.2	18.2	13.7	153	158	84	74
Defoliated Twice	48.3	31.0	40.0	35.4	22.9	18.4	18.9	12.0	85*	57*	47*	40*
Shaded	42.8	31.4	40.0	37.8					81	69	53	49

* Includes tissue removed in second defoliation

The reduction in weight of tissue formed following defoliation is primarily due to the decrease in quantity of photosynthetic tissue. The reduction following shading is due to the decrease in total light energy available to the plants.

Two successive defoliations have given approximately as severe a reduction in quantity of tissue formed as has continued 70% shading. In many ways this is not unexpected. The first defoliation sought to remove about 70% of the photosynthetic tissue, and removing all regrowth a week later gave plants little opportunity to replace it.

Where undefoliated plants remained in full light a greater quantity of tissue was formed at the higher temperature. However, where the plants were defoliated or shaded, that difference disappeared or was even reversed. In some instances defoliated or shaded plants appear to have formed less tissue at the higher temperature. The present data is not precise enough to allow consideration of this situation in detail.

In each treatment short-rotation ryegrass plants formed more tissue in the 15-day period than perennial ryegrass.

The total quantity of shoot tissue formed each day by a ryegrass plant is dependent on number of tillers and their rate of increase, and also on the amount of tissue formed on each tiller. The latter is in its turn related to the rate of appearance of successive leaves on the tiller and the dimensions of those leaves. It is proposed now to examine the influence of the treatment conditions used on these individual features of the plant's growth.

Tillering

Table 2 records the mean number of tillers per plant at the 39th day from emergence. The differences between strains and the responses to treatments agree with an earlier comparison between short-rotation and the English perennial strain—Aberystwyth S23 (Mitchell, 1953a).

TABLE 2. TOTAL NUMBER OF TILLERS—39th DAY FROM EMERGENCE*

Strain	Mean Temperature (°F.)	Full Light	Defoliated Once	Defoliated Twice	Shaded
		C	C	C	C
Short Rotation	57°	32.2	20.1	17.6	12.9
		20%	*24%*	*24%*	*28%*
	72°	30.0	17.7	12.3	9.3
		35%	*30%*	*38%*	*30%*
Perennial	57°	15.9	14.2	11.8	8.7
		25%	*23%*	*28%*	*32%*
	72°	17.2	10.7	6.9	6.5
		21%	*26%*	*24%*	*15%*

*Plotted from large scale graphs. Where harvesting occurred before 39th day, curves are extrapolated.

(1) In all cases short-rotation formed tillers faster than perennial.

(2) Tillering could be slowed down by a single defoliation, and even more by a second a week later.

(3) Continued shading to 30% of full light reduced tiller numbers more than did double defoliation.

(4) Both defoliation and shading had a much more drastic effect on tillering at the higher temperature level. Whereas the plants at 72°F. formed erect tillers with a rather starved appearance when defoliated twice, those at 57°F. formed a compact mass of small but vigorous tillers lying close to the soil surface (Fig. 1).

Fig. 1.—The influence of two different levels of temperature (57°F. on left and 72°F. on right) on the habit of growth of plants of short rotation ryegrass which had previously been defoliated twice.

Figures 2-5 illustrate the influence of representative treatments on the full course of increase in tiller numbers. With undefoliated plants in full light, tillering rate, which is roughly exponential, is increased comparatively little by the summer temperature. Any check to tiller formation resulting from defoliation was temporary. Even plants defoliated twice resumed tillering at approximately the same exponential rate as the undefoliated controls, five to seven days after the second defoliation (Figs. 2, 3 and 4).

A reduction of 70% in light intensity was generally sufficient to wipe out the exponential curve. The number of *fresh* tillers formed each day did not increase as the plant grew but remained constant or in some cases declined almost to zero (Fig. 5).

It has previously been pointed out (Mitchell, 1953a) that the daily rate of increase in number of tillers on a plant is dependent on two factors:—

(a) The rate of appearance of successive leaves on the main stem. This determines the rate at which axillary buds, from which tillers develop, are formed.

(b) The proportion of these buds which grow to visible tillers.

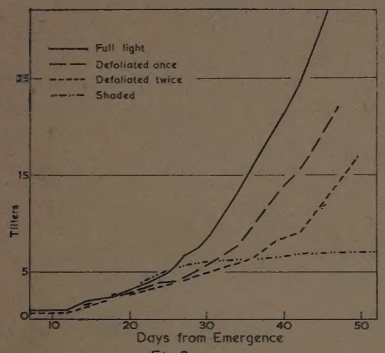


Fig 2

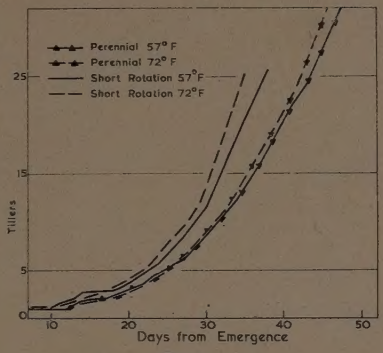


Fig 3

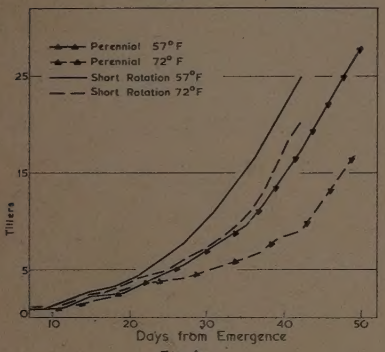


Fig 4

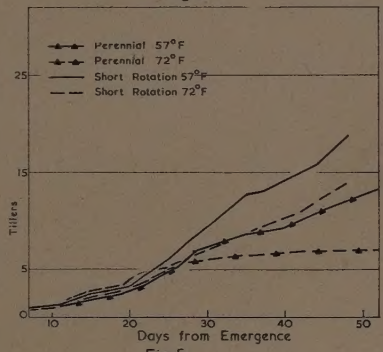


Fig 5

Figs. 2-5.—The course of tillering.—Fig. 2. The effect of full light, one or two defoliations, and shading on tillering of perennial ryegrass grown at 72°F. A comparison of the differences due to strain and temperature is shown for plants grown in full light (Fig. 3); defoliated twice (Fig. 4); and shaded (Fig. 5).

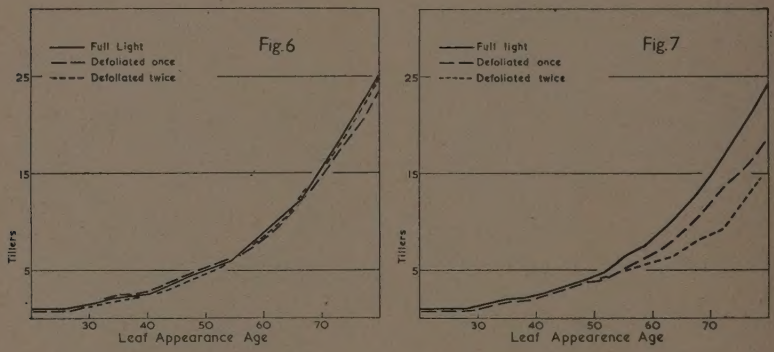
Plants with the leaves on the main stem at an equal stage of development are said to be at the same "leaf appearance age" (Mitchell, 1953a). The number of tillers present at a given "leaf appearance age" is a direct measure of the extent to which axillary buds are developing to form tillers.

TABLE 3. TOTAL NUMBER OF TILLERS—LEAF APPEARANCE AGE 8.0*

Strain	Mean Temperature (°F.)	Full Light	Defoliated Once	Defoliated Twice	Shaded
Short Rotation	57°	24.4	25.0	21.4	16.3
	72°	26.6	23.0	19.5	13.5
Perennial	57°	25.3	24.0	25.6	14.3
	72°	24.2	19.1	15.3	6.9

*Plotted from large scale graphs. Co-efficients of variation as in Table 2.

In Table 3 is given the mean number of tillers on the plants at "leaf appearance age" 8.0, i.e. when the 8th leaf on the main stem was just appearing. The table shows that differences in rate of increase in tiller number between strains and between some treatments arose mainly from a slowing down of rate of appearance of the leaves on the main stem. This is confirmed where the full course of tiller development is plotted according to "leaf appearance age". For example, it was found that at 57°F. the development of axillary buds to form tillers was not affected by either one or two defoliations (Fig. 6), whereas at 72°F. defoliation directly inhibited tiller development (Fig. 7). Situations such as these have been examined in more detail previously (Mitchell, 1953b).



Figs. 6 and 7.—The effect of single and double defoliations on the course of tiller development of perennial ryegrass plants at equal leaf appearance ages: Fig. 6, plants grown at 57°F.: Fig. 7, plants grown at 72°F.

Average Weight per Tiller

Where plants are tillering at an approximately equal rate, tiller weight is primarily determined by the weight of the leaves being formed, e.g., smaller leaf size is primarily responsible for the reduction in tiller weight of defoliated plants at 57°F. (Fig. 8).

Where tillering has been slowed down there is a lower proportion of newly formed, and hence small, tillers on the plant. There is therefore an automatic tendency for the average weight per tiller to rise. This, rather than an increase in weight of individual leaves, is responsible for the tiller weight of shaded plants being approximately equal to, or greater than, that of plants in full light.

Interval between the appearance of Successive Leaves on Main Stem

Fig. 9 shows the number of days required for each group of plants to develop from a mean of 4.5 to 6.5 visible leaves on the main stem. Generally, defoliation and shading treatments commenced shortly before the groups reached a mean of 4.5 leaves on the main stem. Hence, the diagram covers the period when the influence of defoliation treatments on rate of leaf appearance was greatest.

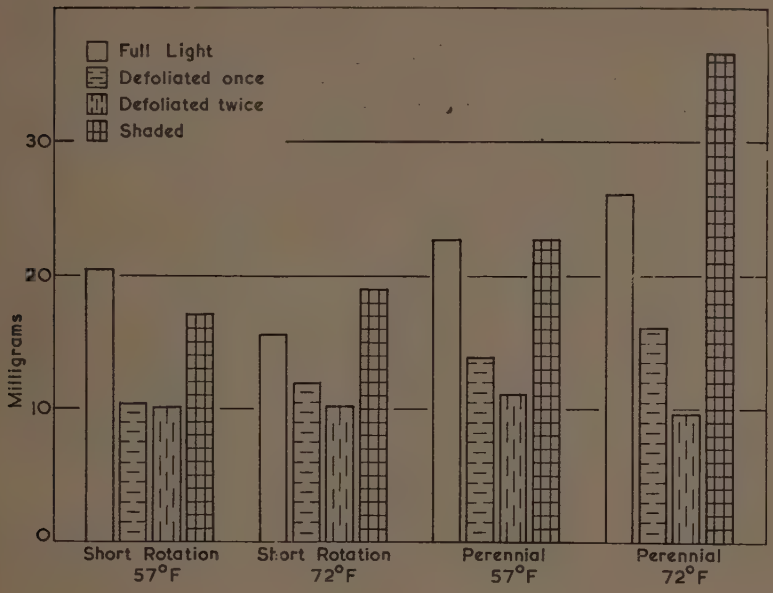


Fig. 8.—Mean weight per tiller of plants when harvested.

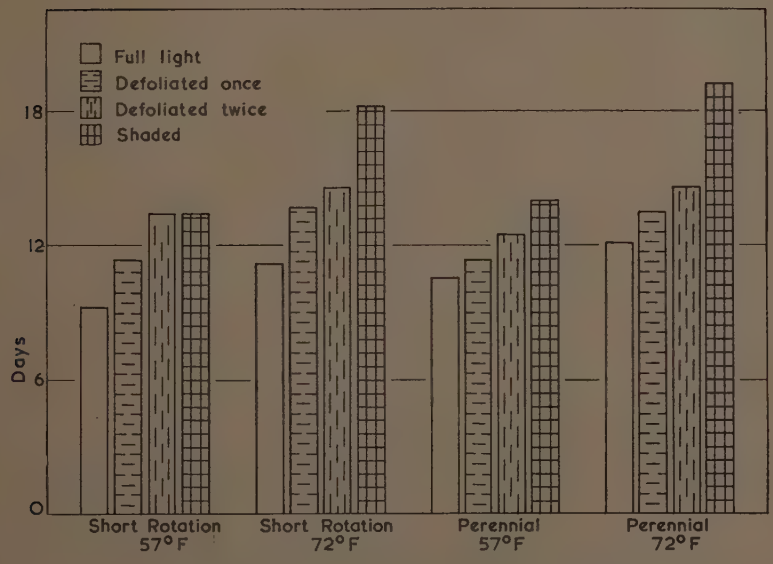


Fig. 9.—Number of days taken by each group of plants to develop from a mean of 4.5 to 6.5 visible leaves on the main stem.

The interval between the appearance of successive leaves was increased by defoliation and to a greater extent by a 70% reduction in light intensity. It was greater in perennial than in short-rotation ryegrass. Where plants were not defoliated leaves appeared more rapidly at the higher temperature, but when plants received two defoliations there was little, if any, difference.

Leaf Dimensions

Changes in leaf dimensions follow a complex pattern conditioned by genotype, light intensity, temperature, and defoliation treatment. Consequently, detailed consideration is not warranted at this stage. The data for the sixth leaf on the main stem, which is selected as representative of the plant as a whole, are pooled in Tables 4 and 5.

TABLE 4. EFFECT OF DEFOLIATION AND SHADING ON DIMENSIONS OF SIXTH LEAF ON MAIN STEM (Averages for both strains)

Treatment	Length (cm.)	Width (cm.)	Area (sq. cm.)	Dry Weight (mg.)	Weight per sq. cm.
	S.E.	S.E.		S.E.	
Full Light	15.0 *(1.3)*	0.39 *(0.03)*	5.18	14.0 *(1.4)*	2.71
Defoliated Once	11.3 *(0.8)*	0.34 *(0.02)*	3.38	8.0 *(0.8)*	2.40
Defoliated Twice	10.3 *(0.6)*	0.30 *(0.01)*	2.80	5.8 *(0.5)*	2.21
Shaded	21.1 *(0.9)*	0.35 *(0.02)*	6.50	11.1 *(0.4)*	1.70

TABLE 5. EFFECT OF TEMPERATURE DIFFERENCES AND OF STRAIN ON DIMENSIONS OF SIXTH LEAF ON MAIN STEM. (Sub-treatments pooled).

Strain	Mean Temperature (°F.)	Length (cm.)	Width (cm.)	Area (sq. cm.)	Dry Weight (mg.)	Weight Area (mg.)
		S.E.	S.E.		S.E.	
Short Rotation	57°	13.1 *(0.9)*	0.42 *(0.02)*	4.98	12.1 *(1.0)*	1.97
	72°	14.1 *(1.1)*	0.33 *(0.02)*	4.26	9.2 *(1.0)*	2.19
Perennial	57°	13.8 *(0.9)*	0.36 *(0.03)*	4.53	10.3 *(0.7)*	2.33
	72°	16.5 *(0.9)*	0.30 *(0.02)*	4.50	11.5 *(0.9)*	2.68

(1) Defoliation reduced length, median width, and dry weight per unit area of the leaves. As a result, both the area and weight of the leaves formed on plants defoliated twice were reduced by over 50%.

(2) The large increase in the length of the leaves caused by 70% shading was offset by a small reduction in median width of leaf and a considerable reduction in dry weight per unit area. As a result, the average weight of the leaves formed in the shade was about 25% less than that of leaves formed at the higher light intensity.

(3) Dry weight per unit area is higher for perennial than for short rotation ryegrass.

(4) At 72°F., leaves were on the average slightly longer, but narrower, and of higher dry weight per unit area than at 57°F.

The dry weight of successive leaves on the main stem of undefoliated plants increased, but defoliation caused an immediate reduction in size of subsequently formed leaves (Fig. 10).

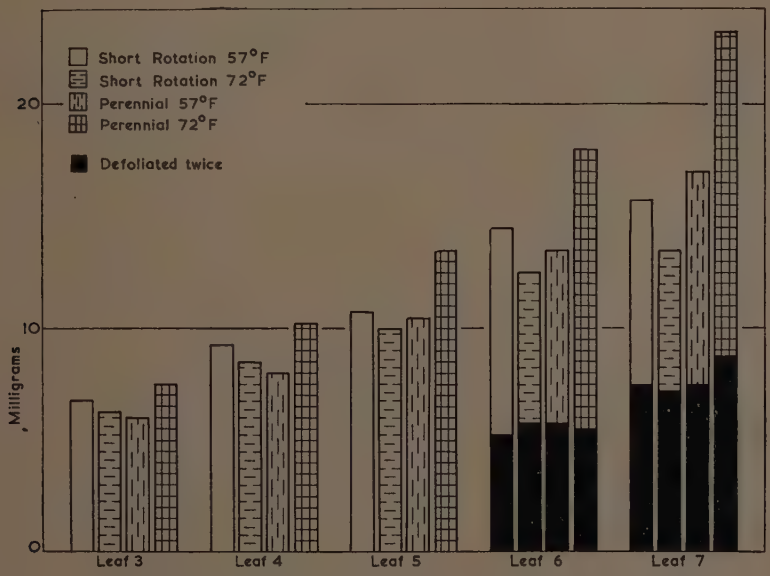


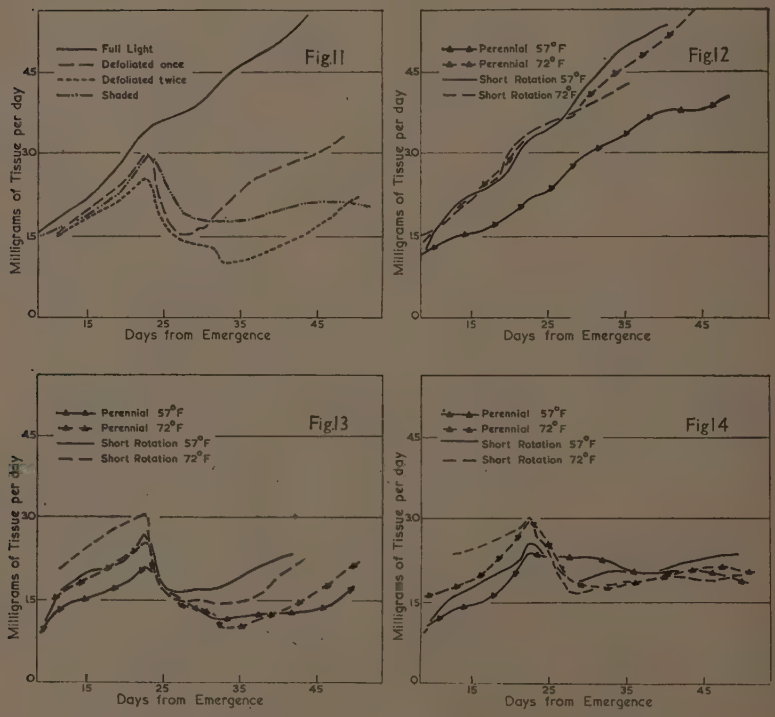
Fig. 10.—Dry weight of successive leaves on main stem of plants grown in full light. The effect of a double defoliation on the size of leaf six and leaf seven is shown. Defoliations occurred during the period when leaf five was developing.

Rate of Tissue Formation by a Single Tiller

From measurements of the daily increase in length of the leaves on the main stem, and the width and dry weight per unit area of successive leaves, the amount of leaf tissue formed each day on the main tiller can be calculated.

There were wide day-to-day variations in the amount of leaf elongation and presumably in the quantity of tissue formed on each tiller. These are primarily due to changes in weather conditions. Their presence is in accord with the earlier conclusion (Mitchell, 1953a) that the pattern and rate of growth of ryegrass plants can be very quickly influenced by a change of environmental conditions. In order to free the data of short term fluctuations and to clarify the general trends all series were given an unweighted 5-point smoothing repeated three times.

(1) The general pattern of response to defoliation and reduction in light intensity, as shown in Fig. 11 for perennial at 72°F., was representative for both strains at both levels of temperature. Where the plants continued to receive a high level of light, and were not defoliated, the quantity of tissue formed each day continued to increase steadily. It is seen that on the tenth day after emergence the main stem tiller formed approximately 1.6 mg. of tissue and on the fortieth day it formed approximately 5.5 mg.



Figs. 11-14.—Tissue formation by a single tiller. Fig. 11 shows the dry weight of tissue formed on successive days on the main stem of perennial ryegrass at 72°F. The differences due to strain and temperature are illustrated for plants grown in full light (Fig. 12), defoliated twice (Fig. 13), and shaded (Fig. 14).

Defoliation caused an immediate reduction in amount of tissue formed. This continued for 4-5 days and then the amount of tissue formed each day once again rose uniformly. Where plants were defoliated a second time a week later, growth on the tiller received a further check which placed its rate of tissue formation about ten to fourteen days behind that of the plant defoliated only once. With light intensity lowered by 70% there was little recovery from the initial reduction in quantity of tissue formed each day.

(2) Where plants were receiving full light the rate of tissue formation by undefoliated short-rotation plants was the same at both levels of temperature (Fig. 12). With perennial the lower temperature slowed down the rate of tissue formation.

(3) For plants which received two defoliations the indications are that, at the lower temperature, recovery was faster with short rotation, but, at the higher temperature, with perennial (Fig. 13). At both temperature levels, the growth on a single tiller of short-rotation was faster than that of a tiller of perennial.

(4) When the plants were 70% shaded the rate of tissue formation on the main stem became approximately constant and settled to approximately the same level irrespective of temperature or strain (Fig. 14).

Discussion

The results presented give further weight to the evidence already adduced (Mitchell, 1953b, 1954) that the tiller, not the whole plant, is the basic unit for consideration in any study of the productivity of ryegrass in a pasture, and of its recovery from adverse conditions.

Although caution is required in using results from single plant studies to predict the reaction of a species or strain in the field, certain deductions would appear admissable.

It would appear that in a pasture the growth of an individual tiller can be limited on the one hand by continuous and severe defoliation resulting from hard grazing, and on the other hand by the mutual shading which occurs if pasture becomes long. The daily rate of production of tissue should be greatest when tillers are held for maximum periods at intermediate heights.

The optimum tiller height for greatest sustained growth of an area of pasture may, however, differ from that indicated by individual plant studies. As pasture growth is basically a process of transferring light energy into plant tissue, it is important that all the light coming in from the sky be intercepted by photosynthetic tissue. A basic inefficiency of many closely grazed pastures is the high proportion of light energy which strikes bare soil. Conversely, in a long pasture, adverse effects of mutual shading should be minimised by the fact that such pastures give a complete cover so that all incident light is intercepted.

Under grazing conditions, temperature levels will play a major part in determining the survival or rate of increase in numbers of tillers

of ryegrass. If temperatures are high a severe defoliation not only checks the development of new tillers but also causes the existing ones to stand very erect. In this position a much higher proportion of the shoot is liable to be removed at a subsequent grazing, thus increasing the adverse effects on tillering. At cooler temperatures not only does defoliation retard the initiation of fresh tillers much less, but the tillers also lie close to the soil surface, making it more difficult for an animal to remove a high proportion of the shoot tissue.

Consequently, during a warm summer, hard grazing is liable to cause a reduction in density of ryegrass in a pasture. Under the cooler conditions of autumn and spring, the growth rate of individual tillers may be reduced by equally hard grazing but they should remain numerous and vigorous.

It is for recovery from thinning out of a species, whether that be due to winter pugging, hard grazing in a hot summer, or shading, that the rate of increase in tiller numbers is of major importance in the field. A relatively small number of vigorous tillers which can increase in numbers by 70-100% *per week,* given adequate light, can very quickly build up the ryegrass component of a pasture. However, if spaces between surviving tillers exceed a few inches, tillering alone will not suffice to quickly fill the gaps.

Although the results suggest a number of other applications, caution is needed in using them to predict growth in the field. It cannot be claimed that all factors influencing the performance of these two strains of ryegrass in a pasture have been taken into consideration or are known.

ACKNOWLEDGEMENTS

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NUTRITION AND SURVIVAL OF *Cercosporella herpotrichoides* Fron AND ASPECTS OF THE WHEAT EYESPOT DISEASE

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(Received for publication, 19 May 1954)

Summary

Failure to secure cultures of *Cercosporella herpotrichoides* Fron from soils, as distinct from wheat tissue isolations, led to experiments on nutrient requirements of this fungus. Although able to utilise inorganic nitrogen in a medium buffered with succinic acid, the fungus grew better in media supplied with peptone. Of amino acids and vitamins possibly connected with this effect, aspartic acid produced a growth level almost equalling that of peptone. Survival as a saprophyte was measured by the sporing capacity of the fungus in wheat stems either experimentally buried in soil or as taken from fields and it was shown that *C. herpotrichoides* persisted so long as infected straw remained undecomposed.

In field trials concerning wheat eyespot disease standard wheat varieties and selections in New Zealand proved highly susceptible but five importations, each with less than 10% straw infection, appeared to deserve further study as a possible source of disease resistance. Stubble burning reduced infective matter more effectively than either very deep or surface cultivations. Field evidence was obtained that wheat lodging associated with eyespot disease was less severe on heavy land where a sole of ryegrass had been encouraged to develop beneath the wheat crop. It is suggested that grass over-sowing on autumn wheat may serve to limit nitrogen supply to an extent unfavourable to *Cercosporella* development without adversely limiting wheat yields. Data are provided showing that despite the existence of a disease factor, average yield of New Zealand wheat has steadily increased. This is attributed to higher fertility levels on land where wheat is now grown in close rotational proximity to ley or short-term pastures heavily stocked with sheep.

Introduction

The potentialities of the fungus *Cercosporella herpotrichoides* Fron in producing a stem footrot of wheat have been demonstrated in published researches of Fron (1912) in France; Oort (1936) in Holland; Bockman (1936) in Germany; Sprague and Fellows (1934) in U.S.A.; and Glynne (1942) in Great Britain. This fungus can possibly be grouped with others listed by Garrett (1950a) and Butler (1953) about which knowledge of saprophytic behaviour is lacking. More information on the carry-over phase of soil-inhabiting organisms associated with root-rot or foot-rot complexes should clarify several aspects of incidence of disease and the aim of the investigation described in this paper is to contribute some information regarding the organism associated with the eyespot disease of wheat.

Experimental Procedure

Cercosporella in soil

Difficulty has been encountered in isolating *C. herpotrichoides* from soil samples. The author, for instance, has not detected colonies of this fungus on agar dilution plates seeded by suspensions originating from soils carrying diseased plants. Even where eyespot disease was established

in variety trials by massive inoculation of wheat crowns, the soil beneath these plants revealed no *Cercosporella,* at least on the evidence of growth of colonies on standard agar media. The characteristic slow rate of growth of *Cercosporella* hyphae seems to preclude visible establishment of this organism on media rapidly overgrown and colonized by fungi and bacteria which grow much more freely. Likewise, when soil from beneath severely diseased plants was examined with slide traps of the type described by La Touche (1948), no isolates of *Cercosporella* were made. Neither could evidence be found of its existence when rhizosphere soil attached to the roots of wheat plants showing eyespot disease was separated and examined by procedures described by Blair (1951). It seemed clear that this fungus, so actively parasitic on wheat, was certainly not dominant in the soils examined. A different approach was made in order to establish whether this fungus could grow in soil. Hyphal pieces (just sufficient to be visible on the end of a needle) taken from the periphery of viable colonies of *Cercosporella* on agar were inoculated into plates (quadruplicate) of prepared soil and incubated. Results were obtained as shown in Table 1.

TABLE 1. GROWTH OF *CERCOSPORELLA HERPOTRICHOIDES* IN NATURAL AND STERILISED SOILS AT TWO WATER LEVELS
(Mean colony diameter in millimetres after 14 days at 21°C.)

	Not Sterilised		Steam Sterilised	
Water-holding capactiy (%)	50	80	50	80
Soil sample 1. Clay loam	—	—	5.8	3.0
2. Silt	—	—	6.4	3.7
3. Sandy loam	—	—	5.5	3.2

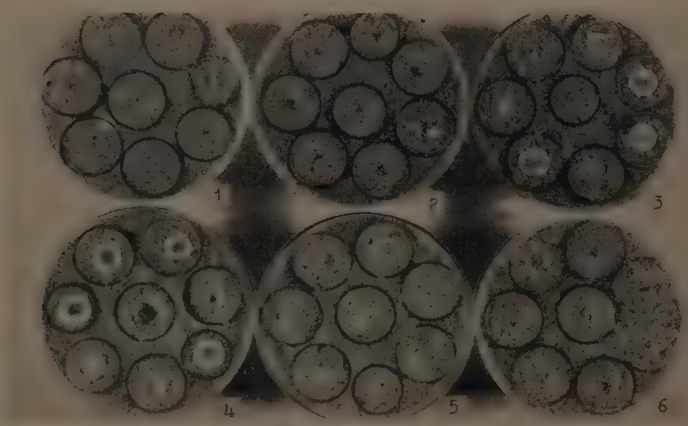

Fig. 1.—Colonies of *Cercosporella* growing in sand circles supplied with nutrients (Table 2).

Photo: V. Stansfield

These results justify the belief borne of earlier failure to isolate *Cercosporella* directly from soil, that this fungus lacks a capacity to grow in an active saprophytic sense in typical soils. This situation may be dictated by sensitivity of *Cercosporella* to antagonistic influences of other microflora, or to specificity by *Cercosporella* regarding nutrient requirements. The latter possibility was examined in the following experiments:

Nutrition: Nutrient requirements of the fungus were examined primarily in sterile washed sand held in dishes containing glass circles and irrigated with culture solutions (Fig. 1). *Cercosporella* colonies were established in the circles by transfer of hyphal pieces (just sufficient to be visible on the end of a needle); this arrangement served to restrict radial extent of colony growth but enabled economical replication to be achieved.

The following steam sterilised media were used (grammes in 500 ml. water):

1. Steinberg R. A. (1935): sucrose, 25; NH_4NO_3, 1; K_3PO_4, 0.2; $MgSO_4$ $7H_2O$, 0.30; pH 6.0 with KOH.
2. Calam (1939): lactose, 15; glucose, 5; citric acid, 5; acetic acid, 1.25; phenylacetic acid, 0.25; $(NH_4)_2SO_4$, 2.5; $MgSO_4$ $7H_2O$, 0.25; KH_2PO_4, 0.50; $CuSO_4$ $5H_2O$, 0.005; $FeSO_4$ $7H_2O$, 0.01; $ZnSO_4$ $7H_2O$, 0.005; $MnSO_4$ $4H_2O$, 0.005; $Co(NO_3)_2$ $6H_2O$, 0.01; NaF, 0.005; pH 5.6—6.0 with KOH.
3. Frank (1948): glycerol, 5; molasses, 5; peptone, 2.5; NaCl, 2.5; KH_2PO_4, 0.03; $MgSO_4$ $7H_2O$, 0.25; $FeSO_4$ $7H_2O$, 0.006; $MnSO_4$ $4H_2O$, 0.02; $CuSO_4$ $5H_2O$, 0.02; pH 6.5 with NaOH.
4. Ainsworth (1947): glucose, 22; peptone, 5; Meat extract, 2.5; $NaNO_3$, 2; KH_2PO_4, 0.5; KCl, 0.25; $MgSO_4$ $7H_2O$, 2.5; $FeSO_4$ $7H_2O$, 0.025; $CuSO_4$ $5H_2O$, 0.008; sod. citrate, 1; sod. acetate, 1; pH to 7.0 with NaOH.
5. Appelby (1947): glucose, 5; asparagine, 1.25; K_2HPO_4, 0.25; KH_2PO_4, 0.25; $MgSO_4$ $7H_2O$, 0.10; NaCl, 0.005; $FeSO_4$ $7H_2O$, 0.005; $CaCl_2$, 0.12; pH 6.4—6.5 with KOH.
6. Steinberg (1939): sucrose, 25; $(NH_4)_2SO_4$, 1.70; KH_2PO_4, 0.275; $MgCl_2$, 0.012; $FeSO_4$ $7H_2O$, 0.001; $ZnSO_4$ $7H_2O$, 0.001; $CuSO_4$ $5H_2O$, 0.002; $MnSO_4$ $4H_2O$, 0.001; Molybdenum salt, 0.001; pH 6.5.

The results in Table 2 checked against composition of nutrient solutions used suggested that protein metabolism of the fungus deserved further study. It will be noted that *Cercosporella* grew satisfactorily within the nutrient range of the six solutions only when peptone was included, and that growth failed when nitrogen was supplied in an inorganic form.

In Table 2 results are given of growth rates, on these media:

TABLE 2. GROWTH OF *C. HERPOTRICHOIDES* IN SIX NUTRIENT MEDIA

(means of 16 replicates on sand cultures)

	Diameter of Colonies After	
	7 days (mm.)	14 days (mm.)
Medium 1.	— Nil	1.56 ± 0.38
2.	— Nil	0.81 ± 0.38
3.	9.22 ± 1.50	12.53 ± 1.50
4.	9.91 ± 1.50	11.93 ± 1.50
5.	2.11 ± 0.38	2.31 ± 0.38
6.	— Nil	— Nil
Significant difference Media 1, 2 & 5 =	1.07 at 5% level	
Significant difference Media 3 & 4 =	9.1 at 5% level	

In other experiments a basal medium of the following composition was supplemented with components of organic nitrogen as listed:—

Basal: (grammes in 500 ml. water) Glucose, 5; NaCl, 1.5; KH_2PO_4, 0.5; $MgSO_4$ $7H_2O$, 0.25; $FeSO_4$ $7H_2O$, 0.025; $MnSO_4$ $4H_2O$, 0.025; $CuSO_4$ $5H_2O$, 0.025.

To this base the following were added in separate portions:

1. Peptone, 0.5% + Meat extract, 0.5%
2. Peptone, 0.5%
3. Meat extract, 0.5%
4. Base alone
5. Asparagine, 0.5%
6. Amino acids (sulphur free), 0.1% each of l-proline, dl-alanine, glycine, lysine, l-leucine.
7. Cysteine hydrochloride, 0.5%.

All solutions were adjusted to pH 6.5 after autoclaving, except that Medium 7 was steamed only. Cultures of *Cercosporella* were established in sand rings and after 10 days' growth at 21°c., colony measurements were obtained as given in Table 3; means of 16 replicates are recorded, colony diameter being expressed in millimetres.

Parallel studies on optimum levels indicated that 0.5% was an optimum level of peptone, as demonstrated in Fig. 2 which shows mean colony diameter from 16 replicates after 14 days' growth.

TABLE 3. GROWTH OF *C. HERPOTRICHOIDES* IN BASAL SOLUTION SUPPLIED WITH PROTEIN AND AMINO ACIDS

Solution	Colony diameter (mm.)
1. Base + Peptone + Meat extract	12.3 ± 0.55
2. „ + Peptone	12.9 ± 0.55
3. „ + Meat Extract	7.2 ± 0.55
4. Base	Nil
5. Base + asparagine	1.7 ± 0.55
6. „ + Amino acids	Nil
7. „ + Cysteine	Nil

Significant difference at 5% level = 1.56

It is understood that peptone contains a variety of ingredients but if its amino acid component accounted for the growth effects shown in the preceding tables it could be expected that some amino acid com-

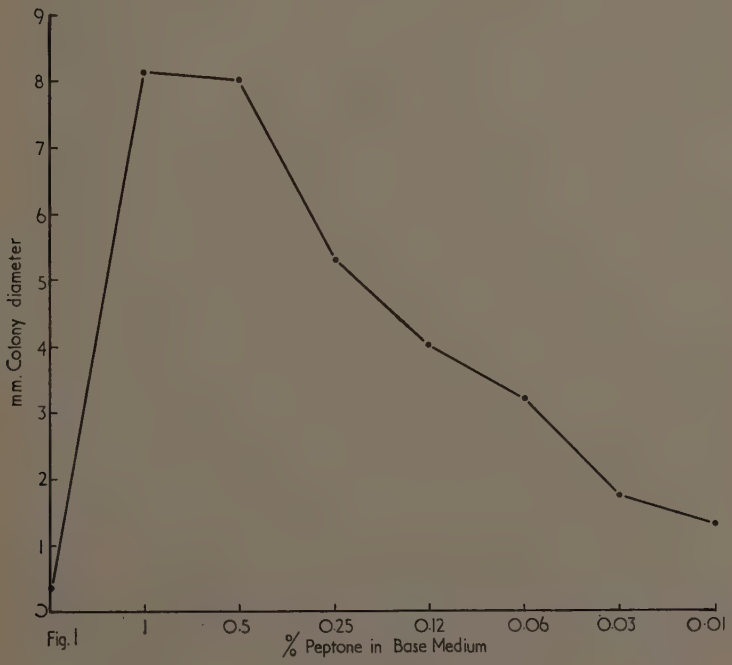

Fig. 2.—Growth of *C. herpotrichoides* in a basal medium supplied with a series of peptone concentrations.

binations would similarly encourage *Cercosporella* growth. Those used in Table 3 were unfavourable. Others which were tested included casein hydrolysate, tryptophane, cysteine—each at 0.5% in the basal medium. None of these produced fungus growth in any degree comparable with that in the base + peptone medium. It was concluded that the efficacy of peptone was likely to be associated with other ingredients than amino acids, namely, vitamins (and growth factors). In an endeavour to promote growth of *Cercosporella* equal to that on the peptone medium, various combinations of amino acids and vitamins were tested, since these may be the active ingredients in the peptone medium. The pH of sterile media was adjusted to 6.5 before addition of individual vitamins the latter being used at 0.5 μg. per ml. The solutions were used to irrigate sand circles and the results obtained are shown in Table 4 expressed as milligrammes oven-dry weight after 14 days, and are means of 16 replicates.

TABLE 4. GROWTH OF *C. HERPOTRICHOIDES* IN PRESENCE OF PEPTONE, AMINO ACIDS AND VITAMINS

Solution	Oven-dry weight (mg.)
Base solution + peptone 0.5%	44.2
Base + casein hydrolysate 0.5%	18.2
Base + casein hydrolysate + nicotinic acid	12.5
Base + casein hydrolysate + biotin	10.0
Base + casein hydrolysate + pyridoxin	4.7
Base + casein hydrolysate + calcium pantothenate	9.0
Base + casein hydrolysate + aneurin	13.6

Thus far, all that had been shown was a favourable response of the fungus to peptone, composed of an amino acid chain. This work now required interpretation in relation to the amino acid content of rotting straw on which the fungus exists (see below) in soil. Information as to what amino acids are to be found in wheat straw has been derived from the chromatographic analyses described by Dent (1948) and Woiwood (1949) and was supplied to the author by Mr. J. Bremner of the Chemistry Department, Rothamsted Experimental Station. The following amino acids have been detected in rotted and unrotted wheat straw: tyrosine, leucine, isoleucine, valine, glucosamine, proline, α - NH_2 -n-butyric acid, hydroxyproline, β -alanine, α -NH_2-butyric acid, lysine, arginine, serine, histidine, threonine, glycine, aspartic acid, and glutamic acid.

Of these, three were selected for comparison with peptone in their effects on *Cercosporella* growth. The weights of the fungus colonies were as follows:— (milligrammes oven-dried—means of 16 replicates)

Base + peptone	340	mg.
Base + aspartic acid	324	„
Base + glutamic acid	100	„
Base + tyrosine	110	„

It was shown earlier that the fungus failed to grow in media supplied with inorganic nitrogen (Table 2). This feature apparently is associated with the effect of pH on utilisation of inorganic nitrogen. Fig. 3 presents data of a check series in which the basal medium plus nitrogen salts was adjusted to pH range using NaOH or HCl and the fungus

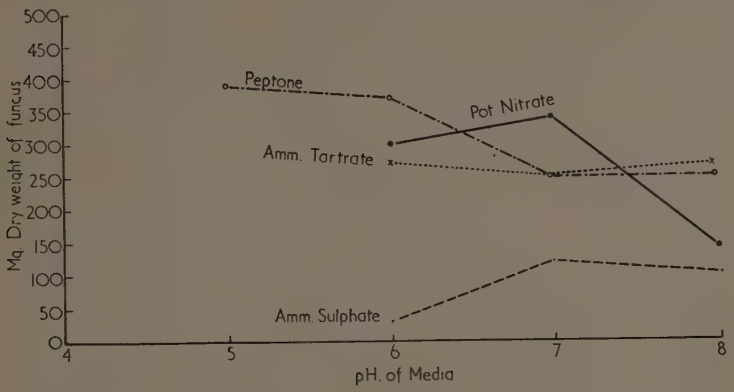

Fig. 3.—Effect of pH of medium on utilisation of inorganic nitrogen by *C. herpotrichoides.*

inoculated into flasks of these media (triplicate). The results show weight of colony growth after 3 weeks, including also inability to utilise inorganic nitrogen at low pH. That the fungus is in fact capable of using inorganic nitrogen, provided pH is optimum and stable was further demonstrated by the inclusion of succinic acid in the medium as a buffer; this was suggested from the work on effects of pH drift on fungus metabolism by Brian *et al.* (1947). After the media had been autoclaved, 1% of succinic acid was added and the desired pH of portions secured with KOH. Results shown in Table 5 are expressed as milligrammes oven-dry weight of colonies; duplicate flasks were used.

TABLE 5. UTILISATION OF INORGANIC N BY *C. HERPOTRICHOIDES* IN BUFFERED MEDIA

Medium	Oven-dry weight after 1 month (mg.)	pH 30.10.52	PH 30.11.52
Amm. Tartrate	216	8.22	6.26
	198	8.22	6.24
Amm. Nitrate	295	8.09	6.44
	286	8.00	6.28
Pot. nitrate	193	8.02	6.86
	176	8.34	6.30
Amm. sulphate	209	8.00	6.25
	195	8.00	6.27
Calc. nitrate	261	8.20	6.64
	249	8.24	6.90

Survival in soil

This aspect was examined by seeking a measure of *Cercosporella* survival after infected straw had been held for a period in soil. In one experiment short pieces of wheat straw were gas disinfected with propylene oxide (Hansen and Snyder, 1946) and then moistened before inoculation with the fungus. The material was held in stoppered tubes until the straws were completely covered by fungus growth. They were then buried one inch beneath the surface of potted soil. On recovering these after an interval of eight weeks, pieces were ground into fragments and plated directly on to Warcup's (1951) medium comprising Dox agar + 0.5% yeast extract, acidified to pH 4.0 by addition of phosphoric acid.

Culture dishes were examined as fungus colonies developed and 14 genera were recognised. Of these *Cercosporella* appeared on the plates prepared after burial for two weeks but in very low numbers, e.g., only three colonies compared with 120 *Penicillium* and 57 *Fusarium*. After burial for four weeks no *Cercosporella* colonies were detected at all; similarly, after eight weeks. It was clear that this particular technique was unsatisfactory as an indication of survival. On the one hand, the well-known slow growth of colonies of *Cercosporella* on agar media would place this fungus unfavourably in comparison with many other soil fungi also arising from straw buried in soil. Furthermore, artificially inoculated straw could not truly represent the sequence occurring under natural conditions when diseased straw was buried in soil. Accordingly, in subsequent experiments pieces of straw obtained from a diseased crop were used. The pieces were cut into short lengths to include the well-known "eye-spot" lesion produced by the pathogenic processes of the fungus in host tissue. In this case the straws were placed at three depths in large crocks of soil, recovery of those at deeper levels being facilitated by attachment to identified threads which led to the soil surface.

Sporing of Cercosporella *in relation to survival*

The working hypothesis adopted was that if *Cercosporella* in these diseased straws could be induced to form spores, this would be indicative of survival of the fungus in straw. In contrast to the extreme difficulty of detecting a colony of *Cercosporella* on an agar plate prior to its being overgrown by other faster growing soil organisms, is the fact that the spores of this fungus are readily identifiable in any mixture of fungus tissue and spores. Glynne's (1953) account of sporing propensity of the organism points out that investigators have consistently isolated non-sporing *Cercosporella* cultures from eye-spot lesions. In pure-culture study the characteristic spores have been induced by methods involving nutritional and physical interactions, as for instance the technique of Sprague and Fellows (1934) in establishing the fungus on sterilised corn-meal, and then placing it outdoors when temperatures fluctuated at the lower levels from −4°C. to 16°C. In this investigation the method used to induce sporing was essentially the same as that of Glynne, namely, to wet the straw tissues on lifting from soil (if necessary) and to maintain them in wet condition, while held in glass vessels outside at winter temperatures, usually between freezing and 16°C. Glynne *(loc. cit.)* suggested that daylight did not seem to influence spore production but in this work under report no spores of the fungus appeared unless the preparations during incubation experienced a period of daylight or of

artificial light. This situation is indicated in Table 6 which summarises the sporing effect obtained when straws with eyespot lesions were held under the influence of moisture (M), temperature (T), and light (L).

TABLE 6. DEVELOPMENT OF EYE-SPOT LESIONS ON STRAW

Treatment designation	Treatment	Sporing	
		9 days	18 days
M	Wet straws; no light, room temperature 20-22c.	Nil	Nil
M-T	Wet straws plus outdoor winter temperature; no light	Nil	Nil
M-T-L	Wet straws plus outdoor winter temperature plus daylight	Profuse	Profuse
T	Outdoor temperature; straws dry, no light	Nil	Nil
T-L	Outdoor temperature plus daylight; straws dry	Nil	Nil
L	Daylight only; straws dry at room temperature	Nil	Nil
L-M	Daylight plus wet straws; room temperature	Nil	Slight

With this basic information on how sporing could be induced, straws with *Cercosporella* lesions were buried, subsequently lifted at intervals, and thereupon retained in wet condition in covered dishes left outdoors (Jan.-March, England) for five days.

Table 7 gives results obtained in this type of experiment.

TABLE 7. SPORING CONDITION OF *CERCOSPORELLA* ON INFECTED STRAWS AFTER BURIAL FOR THREE MONTHS
(Jan.-March, England)

Treatment	Sporing condition	
	On lifting	After 5 days M-T-L
Saturated soil, 4 in. depth	Nil	Profuse
„ 10 in. „	Nil	Profuse
„ surface	Profuse	Profuse
50% saturated soil		
„ 4 in. depth	Nil	Profuse
„ 10 in. „	Nil	Profuse
„ surface	Profuse	Profuse

Identical results were obtained in crocks of soil held at indoor temperatures ranging from 20 to 25°C.

There appeared to be no point in lengthening the period during which straws were buried, as on other field evidence it seemed clear that the fungus survived and was viable so long as infected straw was intact and provided a base for development of the fungus. This field evidence was that *Cercosporella* spores could be induced on straws which were collected from wheat fields eight months after harvest. Then again in Canterbury, New Zealand, straw remnants have been collected from fields two years after an infected crop had been harvested. Such straw remnants have also given rise to *Cercosporella* spores when subjected to the M-T-L treatment.

Field Trials

In 1945, eyespot disease occurred severely in a wheat crop at Lincoln, Canterbury, and arrangements were made for an area of one acre in the affected field to be set aside for field experiments concerning *Cercosporella herpotrichoides*. For seven successive years wheat has been sown on this trial area and hereunder is a summary of results obtained:—

Varietal susceptibility: For three years (1946-48) the standard (New Zealand) varieties were autumn sown as half-drill-strip plots 25 yd. long (8 replicates) at the rate of 90 lb. seed per acre. During the following mid-summer, the plots were sampled (80 6-in. groups of stems per variety) for eyespot susceptibility on the basis of percentage of diseased straws. All standard varieties proved highly susceptible to infection, the following three-year averages of percentage of diseased stems being obtained: Cross 7—85; W.R.I. Yielder—82; Hunters—79; Fife Tuscan—78; Dreadnought—75; Tuscan—74; and Marquis—74.

In the 1952 season, Mr. I. A. M. Cruickshank, Plant Diseases Division, took part in this work and the diseased area was sown with one hundred wheat varieties and selections, included in the current breeding programme of the New Zealand Crop Research Division. The varieties were autumn-sown in short rows with five replications, twenty seeds per row. All straws were examined at maturity and disease ratings assessed on the basis of percentage of stems infected with eyespot disease.

The high susceptibility of standard varieties at present grown in New Zealand was confirmed, but certain imported lines of wheat revealed promise. These were Illini Chief selection, U.S.A.; *Triticum persicum* selection, Cyprus; Hofed 3 (Federation-Hope), Australia; *Triticum vulgare erythrospermum*, Uzbek; Menno, U.S.A. Each of these revealed less than ten per cent of diseased straws. Menno in fact was entirely free of disease lesions but very few straws (21) survived to maturity in this variety.

Stubble disposal: The stubble area remaining after the variety trials (1946-48) were harvested, was given cross-treatments in duplicate strips 2 ch. × 6 yd. as follows:—

Stubble buried deep: Single-furrow swamp plough placing stubble at 12 in. depth followed by normal seed-bed preparation.

Stubble burned: Stubble burned off using a flame-throwing weed burner, before normal seed-bed preparation.

Stubble left near surface: Light skim-ploughing only, followed by tyne-cultivator preparation. The variety trial plots reported earlier were sown across these treatments and the general averages (3 years) of percentage of diseased stems of all varieties for the various methods of straw disposal were as follows: deep—58%; burned—49%; surface—82%. The first two differences are probably not significant but they serve to emphasise the association of infective matter with the surface litter from a diseased crop.

Manurial treatments: Over three years various fertiliser treatments were applied at the time varieties were drilled. Individual results are not presented as Glynne (1945) and Bockman (1952) have reported on this aspect fully. It is sufficient to state that over three years superphosphate at 1 cwt. per acre drilled with seed was not significantly different from untreated regarding percentage of diseased straws. Sulphate of ammonia at 1½ cwt. per acre and blood and bone at 4 cwt. per acre contributed to a significantly higher incidence of disease compared with no-nitrogen plots.

Nitrogen under field conditions: Field surveys in recent years have revealed instances of wheat crop failing on heavy land. Among definable factors, eyespot lodging has been considered a major cause of loss. Certain comparisons were presented in 1950-1951, the most noteworthy being that lodging was less noticeable on three different areas of heavy land where a sole of self-sown grass developed in the ground surface beneath the developing crop.

It was decided therefore to examine this tendency by making sowings of ryegrass over autumn-sown cereals. Two fields were prepared for autumn wheat and drilled with 90 lb. Cross 7 seed together with 1 cwt. superphosphate per acre. Immediately afterwards, 1 bushel per acre of inferior, low germinating, perennial ryegrass (*Lolium perenne*) was drilled across the wheat sowing. When the crops were in ear, line-transect inspections were made and extensive lodging of wheat was revealed on the areas where no grass undercover existed, thus:

Grass undercover	lodged patches of	5	yd.	diameter—	2
No grass undercover	„	„	„	5	„	„	15
	„	„	„	15	„	„	2
	„	„	„	10	„	„	1
	„	„	„	30	„	„	2

Total crop yields of the fields were recorded and the results obtained were 41 bushels per acre for wheat grown with a grass undercover and 22 bushels per acre with no grass. The yields were of low order in keeping with the general results obtaining throughout the New Zealand crop area in the 1952-53 season, which on account of abnormal rainfall, was considered to be the worst within the period of records. Despite the very unfavourable growing season, a 100% improvement in yield on the grass area was striking. It is suggested that the grass undercover has served to limit nitrogen uptake by the wheat, after the manner

described by Buddin and Garrett (1945) and Garrett (1950b) in connection with control of take-all disease under successive cereal cropping. It is emphasised that the situation refers only to wheat growing on heavy land. There the standard New Zealand variety, Cross 7, appears to be particularly subject to lodging (including eyespot disease) when grown on strong land known to be high in nitrogen, following ley, pasture, sheep grazing or peas. It seems that a practical method to limit this may exist in the application of the "Chamberlain" system (described by Buddin and Garrett (*loc. cit.*) by undersowing grass on an autumn cereal.

In concluding this dissertation on aspects of the biology of a wheat pathogen together with some of the field evidences of the disease produced, attention is drawn to Fig. 4.

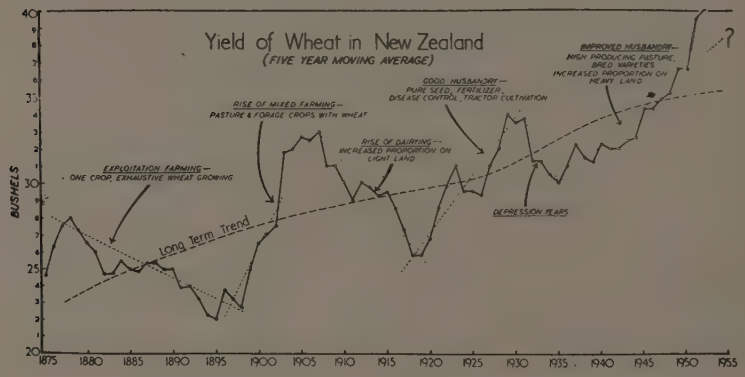

Fig. 4.—Average yield of the New Zealand wheat crop.

These data have been assembled by Associate Professor J. W. Calder, Field Husbandry Department, Canterbury Agricultural College. The steady improvement in average yields of wheat in New Zealand over a 75-year period is most striking. The depressed period in the 1920's is correlated with a period of expansion of dairy farming when many thousands of acres of heavy land, formerly growing wheat, were left in grass for dairy purposes and wheat growing in that period was confined to lighter, lower-yielding land. The yields of the period 1925-40 were closely associated with improvement of wheat seed through certification, seed disinfection to control smut diseases, improved cultivation methods, and the universal adoption of phosphatic fertilisers. The 1945-50 peak of yields is correlated with the crop rotations which are now favoured and which feature wheat growing in close rotational proximity to short-term ley pastures heavily stocked with sheep. The over-all picture therefore is that despite outbreaks of disease of the lodging, root-rot and take-all type, these do not appear on the evidence of Fig. 3 to be serious limiting factors in production over the whole wheat area.

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PEAT PROFILES WHAREROA BLOCK, PAEKAKARIKI, NEW ZEALAND

By N. T. Moar, Botany Division, Department of Scientific and Industrial Research, Christchurch

(Received for publication, 1 July 1954)

Summary

Woody peat in the Whareroa Block has accumulated over a shallow layer of sedge peat, which generally overlies sand. Near the Whareroa Stream the peat is interbedded with silt or clay, and in places rests on gravel. Plant fragments are found at all levels, and *Gahnia* fruits in the woody layer are particularly abundant. Boundaries of areas at equivalent stages of reclamation are indicated and a classification of the area based on recognisable stages of reclamation is proposed.

Introduction

The Whareroa Block, situated in Block II, Paekakariki Survey District, lies between Poplar Avenue and Paekakariki and contains within its boundaries a long, narrow strip of peat about 420 acres in area, bounded to the east by steep greywacke hills and to the west by poorly consolidated sand-dunes. An investigation of the peat area was undertaken in October 1951, on behalf of the Commissioner of Crown Lands, Wellington, with the immediate purpose of assessing the suitability of parts of the area for specific uses such as sports grounds.

The purpose of this paper is to describe the peat, and to discuss the stages in development of the mire. The possibility of utilizing the peat is also briefly discussed.

The mire lies in the southern part of the Horowhenua Plain, which tapers to an end about a mile south of Paekakariki (Fig. 1). At the close of the Pleistocene period the plain began to emerge, but at the time, the southern end suffered a down-warping, so that the sea advanced, cliffing the hills which lie parallel to the coast north of Paekakariki. At a later stage, an increase in the supply of sand to the beaches resulted in the formation of sand-dunes, and this, "assisted by slight uplift, caused the sea to retreat to its present position. Short pauses during this retreat are indicated by the line of swampy depressions parallel to the coast." (Oliver, 1948).

The formation of sand-dunes resulted in water-logged conditions and the initiation of peat-forming processes (Moar, 1952), and although this is not the only reason for peat formation in the district, it is responsible for the development of many mires on the Horowhenua Plain. In the Whareroa Block, the peat is of a fairly uniform nature, but differences occur where the Whareroa Stream flows into the mire. The peat is predominantly woody, and the available evidence shows that at some stage in development much of the mire bore forest. Most of the wood specimens taken from stumps lying on the present surface were coniferous. Plant remains such as seeds, nuts, and leaves give evidence of the nature of the peat-forming plant communities and also indicate differences of accumulation in different parts of the mire.

Draining, burning, and stocking have effectively destroyed the primitive vegetation, and have also resulted in the disappearance of the

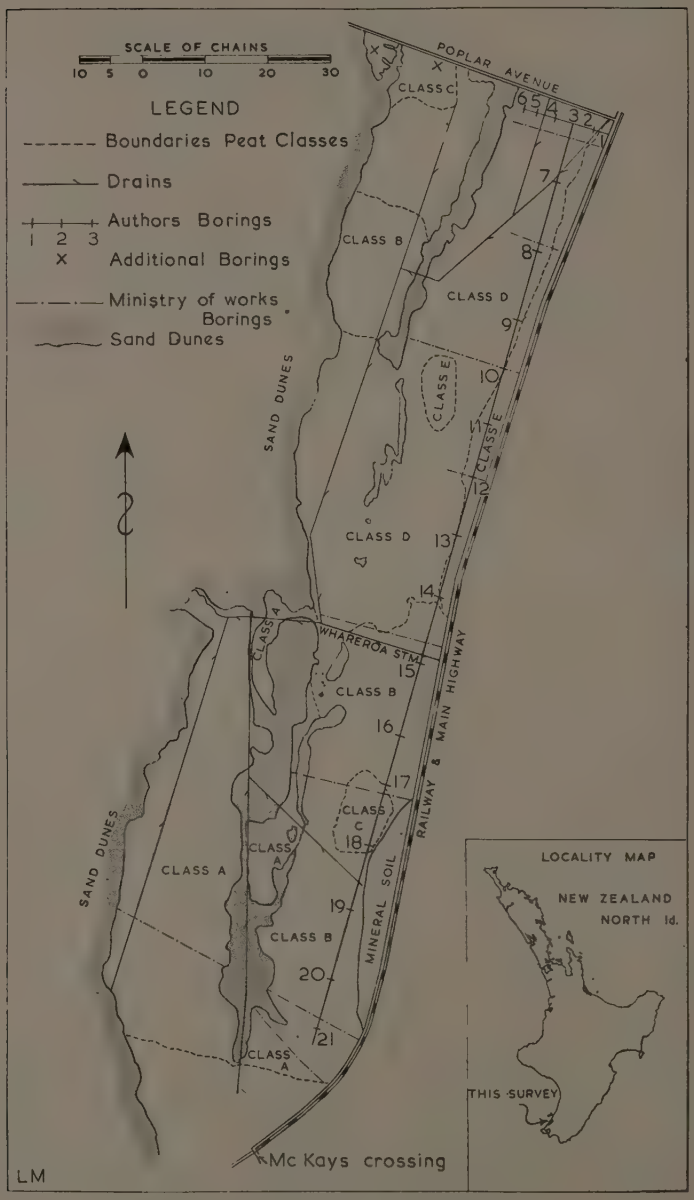

Fig. 1.—Peat area within the Whareroa Block.

upper peat layers. Two hundred acres in the southern part are being farmed and are under pasture; parts of the remaining 220 acres are being utilized to some extent, but most of it has been neglected and is covered by *Leptospermum scoparium* or *Pteridium aquilinum* var. *esculentum*.

Drains in the southern part have been maintained, but those north of the Whareroa Stream have not; the smaller drains are overgrown, and the larger ones are deteriorating.

In areas not fully reclaimed, the surface is hummocky, and near the margins it is sometimes deeply pitted—the result of frequent fires that sweep across the area. Stumps of large trees occur over much of the surface, and are sometimes so dense that further reclamation would be difficult.

VEGETATION

The vegetation is similar to that described in the Paraparaumu district (Moar, 1952) except that *Ulex europaeus* is absent.

Much of the northern end has been recently burnt and dead plants of *Leptospermum scoparium* are scattered over the area. The plant cover of *Pteridium aquilinum* var. *esculentum* and *Cladium teretifolium* is open, and ranges in height from 6 in. to about 3 ft. The *Pteridium* tends to be taller and denser on the hummocks while *Cladium* prefers the hollows. Other species present include *Hypochaeris radicata, Anthoxanthum odoratum, Rumex acetosella, Trifolium dubium, Haloragis micrantha, Nertera dichondraefolia,* and *Lotus uliginosus*.

Leptospermum scoparium reinvades, and in one regenerating area has formed a stand 3 ft. high. *Gleichenia circinata* occurs at the edge.

Where *Leptospermum* has not been burnt for some years it is up to 15 ft. high, and, although the canopy is close, individual plants are widely spaced. In damp situations a scattered ground layer of grasses has developed, but in drier parts *Pteridium* is present.

Close to the western margin *Pteridium* is dominant. A dense cover of herbaceous plants in small open spaces includes in order of abundance *Trifolium dubium, Holcus lanatus, Hypochaeris radicata, Rumex acetosella* and *Anthoxanthum odoratum*.

In a hollow on the western edge *Cladium teretifolium, Gleichenia circinata* and scattered mounds of *Sphagnum* are found under *Leptospermum scoparium*.

UTILIZATION CLASSES OF PEAT

The potential value of an area may be assessed by studying the surface vegetation and the peat profile, including factors such as the botanical composition and the degree of consolidation of the peat. A simple classification based on such factors distinguishes recognisable stages in reclamation and should be applicable to any area under consideration. Five classes are recognised and defined as follows:—

Class A: Fully reclaimed area which could be used for any general purpose including arable farming. Because of careful management, areas included in this class have a well developed pasture established on them. Drainage is good and the drains are maintained.

Class B: Area reclaimed so that it could be used for pasture farming. In the Whareroa Block, Class B areas differ from Class A areas only to the extent that the pasture is less dense and weeds such as *Juncus* spp. and *Pteridium* are present.

Class C: Areas cleared of any surface stumps and scrub and beginning to provide grazing for stock. Introduced grasses such as *Holcus lanatus* and *Anthoxanthum odoratum* are present in the Whareroa Block.

Class D: Areas that need clearing before being used for any purpose. Drainage is not good and consolidation is not far advanced.

Class E: Areas that would be difficult to use because of the density of stumps or because of the deeply burnt peat surface or because of a combination of the two factors. A sixth class could be defined as an area of raw peat on which reclamation has not been initiated.

Peat Profiles

This study is based on the results of two bore-lines A-B and C-D, entailing 21 separate borings as well as occasional bore-holes made at various localities on the mire (Fig. 1). In addition, the writer has had access to the results of numerous borings made by the Ministry of Works.

The deepest peat occurs in the northern part of the mire, and although the underlying surface is uneven, the peat gradually becomes shallower towards the southern end. On Line A-B, depth varied from a minimum of 10 ft. to a maximum of 14 ft. 2 in. (Fig. 2). From Bore-hole 3 to Bore-hole 11 on Line C-D depths varied from 7 ft. to 9 ft., but beyond this point the exact depth of peat was difficult to determine as layers of clay were interbedded with the peat. The surface layer of peat at Point 21 was only 10 in. thick, but information supplied by the Ministry of Works shows that a layer of peat 10 ft. thick underlies clay near this point. Ministry of Works borings indicate that the inter-bedding layer of clay is absent in the central part at the southern end, and that the peat ranged in depth from 3 ft. to 10 ft. with the deeper layers occurring near the eastern margin. Clay appears again at the western edge where a layer 3 ft. thick lies between a 2 ft. thick layer of surface peat and a buried peat layer, 4 ft. thick.

The peat is well decomposed, and contains quantities of sand and silt blown from the sand-dunes, or washed in from the adjacent hill-sides. It is predominantly woody, and stumps, some of considerable size, occur at all depths, particularly in the upper 6ft. The woody peat is characteristic of the upper layers and is thickest at the northern end near Poplar Avenue.

For a distance of about a mile from Poplar Avenue southwards, surface layers of peat, to a maximum depth of 30 in., contain abundant remains of rhizomes of *Gleichenia circinata*, and frequent rhizomes of *Pteridium;* many of these belong to living plants of the present vegetation. The layer of woody peat has a maximum depth of 6 ft. on Line C-D, and remains constant in depth until it abruptly ceases near Point 14. The quantity of wood in the peat is shown by the deeply

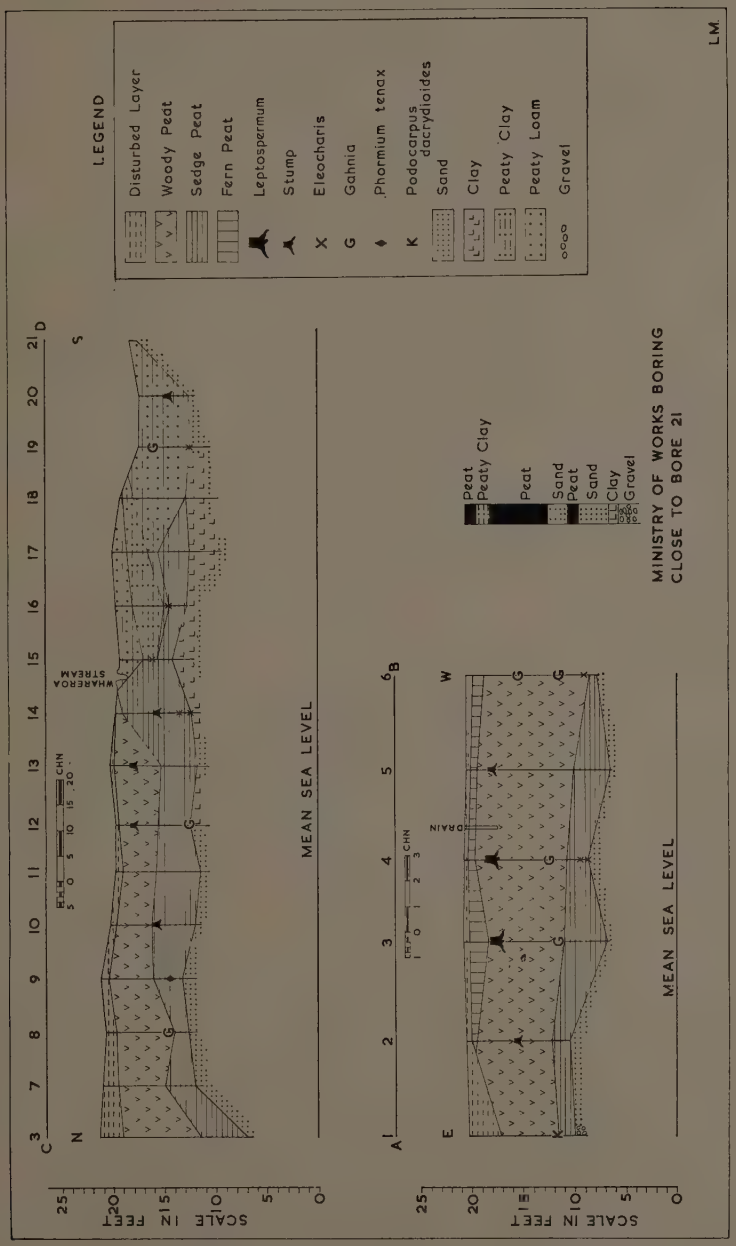

Fig. 2.—Peat profiles, Whareroa Block mire.

burnt marginal areas north of the Whareroa Stream, and the numerous stumps on much of the surface just south of the stream. Remains of fern, rush, and sedge are present in the wood layer, but sedge and rush peats predominate only in the lower layers. The sequence of the different layers of peat at the northern end is illustrated by the profile of Bore-hole 4:

Depth (in.)	
0 - 9	Disturbed layer: bracken rhizomes frequent, representing the induced surface vegetation, H7.*
9 - 30	fern peat; stumps of *Leptospermum* at depth of 12 to 24 in.; *Gleichenia* rhizomes frequent; *Pteridium* rhizomes; H8.
30 - 70	woody peat; wood at 40 in.; H7-9.
70 - 100	woody peat; fibrous, with sedge fragments throughout; *Gleichenia* rhizomes common; wood at 80 in.; fruits of *Gahnia* sp. at 100 in.; H8.
100 - 120	plastic peat; sedge and wood fragments mixed; H8.
120 - 140	sedge peat; fern and wood fragments at 130 in.; H9.
140 - 160	peaty sand; sedge fragments present; nuts of *Eleocharis* sp. collected.

Three stumps of *Leptospermum* were found in a pit 2 ft. deep, dug at the site of this bore-hole. The tops of the stumps were 1 ft. below the present surface.

A similar sequence to the above was recorded at many bore-holes, but at some, a sedge layer was more prominent. *Phormium* leaves were recorded at a depth of 6 to 12 in. near Point 9, Line C-D, and at Point 7, Line C-D, large pieces of bark of *Cordyline australis* were noted just below the surface. South of the Whareroa Stream the marginal peat is interbedded with clay and sand. In some cases peat has disappeared from the surface, and is replaced by a peaty loam, or loamy soil. Bore-hole 17 illustrates the general nature of the peat, and the layering, in this part of Line C-D.

Depth (in.)	
0 - 20	peaty loam; slightly fibrous.
20 - 22	transition to peaty clay; wood fragments present.
22 - 40	peaty clay; rush, sedge, and wood fragments present.
40 - 50	plastic peaty loam; slightly fibrous; transition layer.
50 - 60	sedge peat; wood and rush fragments present; sandy from 60 in. to 84 in.; H7-8.
90 - 100	clay.

In a small frequently flooded basin beside Poplar Avenue and separated from the main accumulation by a ridge of low sand-dunes (Fig. 1), the peat was similar to that already described, but rush remains were frequent, and *Sphagnum* leaves, not recorded elsewhere, occurred. There was a considerable admixture of sand, no doubt a result of the proximity of sand-dunes.

*Degrees of decomposition are classified according to von Post's scale: H1 to H10.

Depth (in.)

0 - 10	slightly fibrous, rush fragments.
10 - 60	*Sphagnum* present at 10 to 14 in.; *Leptospermum* at 30 in.; H8.
60 - 88	many woody fragments; sand present; H9.
88 - 100	dark grey-brown; top 2 in. a transition to sand; some rush fragments present.

Plant remains in the peat

The Whareroa Block peat is rich in plant remains, the commonest being nuts of *Gahnia* sp. These were found in most bore-holes, generally near the surface, but they also occur at considerable depths, as at Bore-hole 3, where some were recovered at a depth of 9 ft. 2 in. Nuts of *Eleocharis* sp. are present at various depths, ranging usually from 2 ft. to 13 ft., but are generally not as common as those of *Gahnia*. They are, however, plentiful in the transitional layers underlying peat south of the Whareroa Stream. A few leaves and capsules of *Leptospermum* were also found. An interesting find of a branchlet of *Podocarpus dacrydioides* (Fig. 3) occurred in Bore 1, Line A–B at a depth of 12 ft. 10 in., in a peaty loam which consisted mainly of sedge fragments.

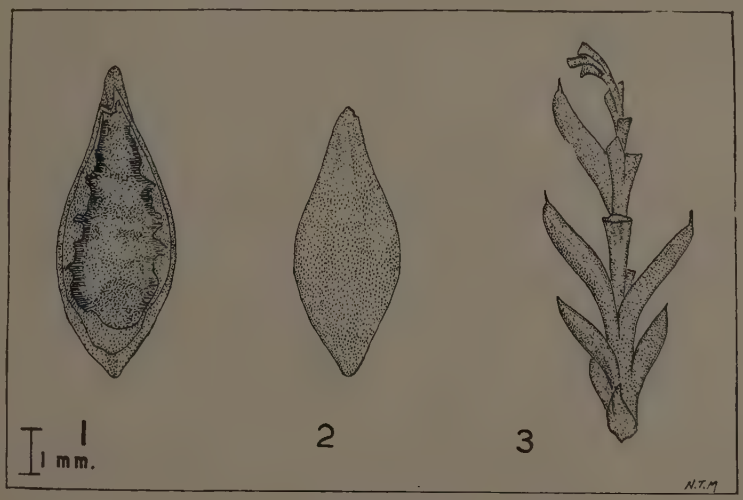

Fig. 3.—1. *Gahnia* fruit, cut longitudinally
2. *Gahnia* fruit, surface view
3. *Podocarpus dacrydioides* branchlet from bore-hole 1, at 12 ft. 10 in.

Wood samples taken from stumps in surface peat were collected and the species identified are listed:

Podocarpus dacrydioides
P. spicatus
P. totara

Dacrydium cupressinum
Laurelia novae-zelandiae
Dysoxylum spectabile
Metrosideros robusta
Leptospermum scoparium

Most of the specimens were collected on the middle or on the southern part of the mire, and generally close to the margins, but this does not imply that wood is necessarily confined to shallow peat, for stumps *in situ* occur on the surface of peat more than eight feet deep.

UNDERLYING STRATA

The peat generally overlies sand, which could not be penetrated with the Swedish peat auger, so that relevant data have been taken from more elaborate borings made by the Ministry of Works. Sand varies in thickness from 1 ft. to 10 ft. and, north of the Whareroa Stream, rested on gravel, except in a narrow zone close to the eastern margin, where a shallow layer of clay no more than 1 ft. thick occurred between sand and gravel. The gravel was not penetrated. Immediately south of the Whareroa Stream marginal peat is underlain by a layer of peaty clay which in turn rests on sand. The sequence is illustrated by a boring near Point 16, 20 ch. from the stream.

Depth (in.)	
0 - 96	peat.
96 - 120	peaty clay; transitional layer, clay-like organic layer.
120 - 156	sand.
156 - 204	clay.
204 +	gravel.

Away from the margins the sequence is similar to the northern portion.

At the southern extremity of the mire, Ministry of Works' borings show that there is a wide band of peat interbedded with clay or sand, and a profile indicates the complexity of this area:

Depth (in.)	
0 - 12	peat.
12 - 30	peaty clay; transitional layer.
30 - 96	peat.
96 - 120	sand.
120 - 132	peat.
132 - 168	sand.
168 - 180	clay.
180 +	gravel.

The central part of the southern end is similar to the northern portion, except that sand overlies water-bearing sand, and gravel is not recorded. As already stated, a clay layer 3 ft. thick lies between two layers of peat, a surface layer 2 ft. thick, and a buried layer, 4 ft. thick, at the western margin. The bottom layer of peat overlies sand 7 ft. thick, resting on a layer of water-bearing sand of unknown thickness.

DISCUSSION

Formation of the Mire

A view of the mire from the hills on the eastern margin gives the impression that at one time a lake or lagoon lay in the basin between the sand-dunes and the hills. A study of the peat profiles and the underlying strata suggests that this was not the case, for there is no evidence of an aquatic stage in the bottom layers of peat, but, before the deposition of sand at the northern end, it is possible that water lay in a depression close to the hills for short periods at least, for here a shallow layer of clay overlies the gravel.

Harris (1951) discussed the succession of plant communities in a Wallaceville mire and considered that the first stage, a swamp with *Typha* and *Phormium,* was invaded by *Leptospermum,* which initiated the next shrub stage. The final stage "is a sedge swamp in which *Gahnia* apparently was dominant". A study "of the peat and pollen profiles suggests . . . that at an early stage peat formation was interrupted, and the area became wooded over, and that when peat formation was resumed it continued under a gradually rising water table until the swamp was artificially drained".

Stages of peat formation in the Manawatu district have been briefly discussed by Aston (1920), who comments as follows: "The final development into swampy forest, with white pine and pukatea as the dominant forest trees, may be assumed to be the final stage in the development as a swamp, and one which would persist for a long period." The early stages of accumulation in the Whareroa Block mire are considered to be similar to that of the Wallaceville area. The surface would be water-logged, but not covered with open water, and the vegetation would include plants such as *Carex secta* and *Eleocharis acuta,* and other species of wet places.

Shrubs, including *Leptospermum,* invaded the area as peat accumulated; this species persisted for a long period, in contrast to the "swamp" plants which were of a transient nature. *Podocarpus dacrydioides,* and *Laurelia novae-zelandiae* entered the peat-forming community, particularly near the edge of the mire, and these, as well as *Leptospermum,* have contributed to the woody peat. The presence of *Gahnia* nuts at various levels, as well as the numerous stumps at and near the present surface suggests that a forest such as that described by Aston (1920) and classified by Cockayne (1928) as "semi-swamp" forest developed in parts of the Whareroa Block.

Slight differences in development have occurred at the southern end in the vicinity of the Whareroa Stream. Silt deposited from flood water has become interbedded with peat, and the stream has formed a fan of gravel and silt which extends for some distance across the mire. The influence of the stream is shown by the swamp vegetation which has persisted for a long time, particularly in the vicinity of the stream. Forest species were also present, and in the shallower parts "swamp forest" was apparently well established.

At the northern end of the mire there is evidence that in the deeper central areas *Leptospermum scoparium* was followed by *Cladium teretifolium* and *Gleichenia circinata* which later became dominant. Stumps of *Leptospermum* are generally a little beneath the present

surface and *Gleichenia* rhizomes and remains of rushes occur in the first 20 in. of peat. As some 3 or 4 ft. of peat at least has been destroyed, it is probable that these species were formerly more widespread.

In the final stage of the mire, the southern portion and the marginal areas were forested, with swamp vegetation in the vicinity of the Whareroa Stream. The deeper central parts of the mire, while probably carrying scattered forest species and *Leptospermum,* were assuming the aspect of a bog, the vegetation consisting of *Gleichenia, Cladium,* and *Sphagnum* species.

Reclamation

Forest peats present special difficulties in reclamation. The Whareroa Block mire is no exception, as although the peat is fertile and could be utilized, the removal of wood and stumps would be an expensive item and for a time at least a recurring one, as, after one layer was removed another would appear as the peat consolidated. Marginal areas, which are probably the most fertile, have a great concentration of stumps, so that they would be difficult to reclaim. The bottom layers of peat are at least seven feet above sea-level, so that there would be no fear of the peat falling below sea-level, but, as the northern peat is generally deeper, precautions would need to be taken in order to prevent its surface falling below the level of that in the southern part, and thereby creating additional difficulties in drainage.

The classification already described assumes that before peat within the area discussed can be used for any purpose whatever it must pass through a pasture or turf stage. Although many peat accumulations may be suitable only for farming, the classification as proposed is broad enough to be applied to any area being investigated from the point of view of utilization.

Acknowledgements

The writer wishes to thank the Ministry of Works for providing data of borings, the Commissioner of Crown Lands for providing aerial photographs and levels of the bore-lines, and Mr. R. Orman, Forest Research Institute, for identifying wood samples.

Species List

Botanical Name	Common Name
Pteridium aquilinum Kuhn var. *esculentum* Hook f.	bracken
Gleichenia circinata C. Christen.	umbrella fern
Podocarpus dacrydioides A. Rich.	kahikatea
P. spicatus R. Br.	matai
P. totara D. Don.	totara
Laurelia novae-zelandiae A. Cunn.	pukatea
**Rumex acetosella* L.	sorrel
Haloragis micrantha R. Br.	—
Leptospermum scoparium Forst.	manuka
Metrosideros robusta A. Cunn.	rata
**Trifolium dubium* Sibth.	suckling clover
**Lotus uliginosus* Schkuhr. (*Lotus major* Sm.)	—
**Ulex europaeus* L.	gorse
Dysoxylum spectabile Hook. f.	kohekohe

Nertera dichondraefolia Hook. f.	—
**Hypochaeris radicata* L.	catsear
Cladium teretifolium R. Br.	—
Carex secta Boott.	nigger head
**Holcus lanatus* L.	Yorkshire fog
**Anthoxanthum odoratum* L.	sweet vernal
Gahnia sp.	—

*Introduced species.

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USE OF HONEY BEES AS POLLINATORS IN UNHEATED GLASSHOUSES

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(Received for publication, 17 June 1954)

Summary

Isolation of insect-pollinated plants for stock-seed production is a major concern in vegetable breeding. Insect-proof glasshouse cells, holding about 40 cabbage plants have successfully been used at the Crop Research Division. To obtain a satisfactory yield of seed under these conditions, it is necessary to introduce insects into the cells to cross-pollinate the selected plants.

A method of using honey bees as pollinators in glasshouses was successfully tried in 1953 and a satisfactory yield of seed obtained. The honey-bee technique is described and the associated problems are discussed.

Introduction

Since its inception in 1946, the Vegetable Section of the Crop Research Division has been concerned mainly with the development of pedigree strains of vegetables to suit New Zealand conditions. In the course of this work, the problems associated with the production of nucleus seed from selected Brassica plants have been a major concern, more especially the aspect of cross-pollination and isolation among the several strains of cabbages and cauliflowers handled.

Most vegetable crops, when grown for seed production under natural outdoor conditions, depend on insects or wind for effective cross-pollination. Isolation from possible contaminating sources can be achieved in commercial seed-growing areas by (a) ensuring that crops flower at different periods, (b) maintaining sufficient distance between crops, (c) by planting large areas for seed production. With large masses of plants grown for seed, fairly small distances between varieties and strains will suffice to exclude serious contamination by foreign pollination. However, as the number of plants grown for seed becomes smaller, the distance necessary to achieve the same freedom from contamination becomes greater.[1] At a research station limited in area, and dealing with small numbers of selected plants for stock-seed production, isolation by distance becomes impracticable, and some form of enclosure must be used from which contaminating insects can be excluded. Also, nucleus seed must be more carefully protected than commercial seed, since any contamination would be cumulative in succeeding generations, and if the contamination is of the "hidden" type, i.e. not recognisable as a phenotype, then the hybrids can never be wholly removed by roguing in later generations.

To overcome the difficulty of adequate isolation in dealing with the breeding and seed production of all the farm and garden crops handled by the Crop Research Division, a range of lean-to glasshouses, divided into 30 separate units or "cells", was erected at Lincoln in 1951-52. Individual cells are 14 ft. × 10 ft. × 12 ft., and all ventilators are covered with fine wire gauze to make them insect-proof. To ensure a movement of air through the cell, electric suction fans have been

installed at the top of the back wall. Mounted over the fan opening on the outside wall is a frame containing four fins or louvres, which are automatically open when the fan is running (by the outward movement of air) but which drop shut when the fan ceases to run.

The fan is thermostatically controlled to come in on any setting from 40°F. to 85°F.

When the plants are moved into the glasshouse cell for the flowering period, it becomes necessary to introduce clean insects into the cell to carry out the necessary pollination, since hand-pollination is too laborious to be practical, and is not so effective as insect pollination. In previous years, clean bumble bees had been used, but this method was not entirely satisfactory, since in cold and overcast weather the bees were difficult to find. Once caught, they had to be washed free from contaminating pollen. This method also had the disadvantage of gradually reducing the population of bumble bees, since the majority of bees caught early in the season were queens, and if put in the glasshouse cells for pollination work, they eventually died without forming nests and laying eggs. Dutch workers[2] are using diseased queen bumble bees for carrying out pollination under cages. These queens, through a parasitic disease, are incapable of producing eggs, and therefore no reduction of the population of bees is incurred through their use as pollinators.

Honey bees have been used in Australia for cross-pollinating selected cabbage plants under cheesecloth cages[3]. To the author's knowledge, honey bees have not previously been used in New Zealand as pollinators of vegetable seed plants in glasshouses.

In 1953, therefore, when planning the production of nucleus seed from selected savoy plants of a strain of "Best of All" developed over the last six years at the Vegetable Section, it was decided to try honey bees as pollinators in glasshouses, and the following is a description of the technique adopted.

EXPERIMENTAL PROCEDURE

Cultivation and Selection of Plants

A crop of savoy cabbage was grown at Lincoln in 1953 for progeny testing and selection of plants for stock-seed production. This was the third generation of selection and progeny testing in this strain of "Best of All", which has now reached a high standard of uniformity. The crop matured at the end of April 1953, and about 80 plants were selected for seed production, out of a total of 1,452 plants. Directly after selection, the heads of the plants were "raced", which consists of making two cuts across the head at right angles to each other, to a depth of about 3 in. to enable the main flowering stem to develop.

Early in May, 42 of the selected plants were lifted with a good ball of soil, and potted in 10 in. concrete pots, using fine turfy loam mixed with sand as a potting medium. The pots were then sunk to their rims in the open ground in a sheltered position, where they remained throughout the winter months of June, July, and August. The remainder of the selected plants were left in the open field for the winter months.

This was the first season that a technique of potting selected plants out of the field was tried. Only the potted plants were intended for

seed production, the remaining plants left in the field being held as a reserve. However, a second glasshouse cell became available, and it was therefore decided to use the reserve plants for seed production in the second cell.

It was found that the extra work involved in potting the plants directly after selection is offset by the following advantages:

The ground on which the crop was grown is quickly cleared, and so can be ploughed and cultivated early.

When in pots, the selected plants occupy a smaller area for the winter months, since they can be stood in a group instead of remaining as isolated single plants scattered throughout the field. A temporary shelter can then be erected over them if severe weather threatens.

The plants can be left standing outside until the flower buds begin to open. This results in a good sturdy growth of the main flowering stem. When plants are moved direct from the field into the glasshouse cell, the development of the main flowering stem becomes weak and drawn under glasshouse conditions.

When the plants are well established in pots, the root system receives no check when the plants are moved into the glasshouse for the flowering period.

The watering of plants individually is better controlled.

On 11 August, the potted plants were given a topdressing of a general fertilizer to encourage healthy growth of the main flowering stem. As the flowering stem developed from the head, the old wrapper leaves were gradually stripped off at the base to prevent entry of disease through decaying leaves. About two weeks before the plants were moved into the glasshouse, they were sprayed several times to ensure that only plants free from aphids were moved into the glasshouses.

On 31 August, both the selected plants in pots and those left in the field were moved into two separate glasshouse cells for flowering and seed production. The potted plants were sunk to their rims in the soil of the cell, and the plants lifted direct from the field were transplanted with a good ball of soil into the well prepared soil of the second glasshouse cell. All plants were staked individually with three wooden stakes to each plant. There were 42 potted plants in one cell, and 38 transplanted plants in the second cell.

The Flowering Period

Nucleus hives of honey bees were moved into the glasshouse cells on 22 September, when the majority of plants were commencing to flower.

A strain of Italian bees was used, and each nucleus hive consisted of six frames. Two nucleus hives were placed in each cell, and were mounted on boxes so that the openings of the hives were on a level with the flowering branches.

A supplementary feed of honey was given to the bees before they were moved into the glasshouse and this lasted for the whole of the

pollinating period. By means of a bottle drip-feed, which was set up near the landing board of each hive, a supply of free moisture was also made available to the bees without exposing them to the danger of drowning.

Some form of shading on the glass was essential, since if left unshaded, the bees would tend to fly up towards the light. A cheesecloth screen was placed over the fan to prevent the bees from being damaged in the blades.

Temperature

The control of the temperature within the glasshouse cell was of the utmost importance during the pollination period to prevent loss of bees through very high temperatures. Daily readings of the maximum and minimum thermometer were recorded, and comparisons made with outside screen readings for the same period. Exceptionally warm and sunny weather prevailed during the spring months, and although the thermostat of the fan was set at 65°F., the temperature inside the glasshouse cell frequently rose to over 80°F.

The hives remained in the glasshouse cells from 22 September to 23 October and during that period the average maximum temperature was 78.3°F. in the cell, and 59.4°F. in the screen outside. The average minimum temperature in the cell for the same period was 43.5°F., and in the screen outside it was 39.4°F. The highest maximum temperature recorded in the cell during the period of pollination was 100°F. on 21 October and the lowest minimum temperature was 35°F. on 1 October. The cell was unheated.

During the time the hives were in the glasshouse cell, there was a high mortality rate among the bees. This loss was due partly to the natural life span of the bees, and partly to the high temperatures in the cell. In spite of the apparent loss, the total population of the hive appeared to be maintained and the hives were considered to be in a satisfactory condition when returned to their owner.

For the first week after the hives of bees were introduced into the glasshouse cell the bees tended to fly up to the roof and congregate along the beams. Later, however, the bees flew directly to the flowers from the hive, and by the time the plants were at their peak of flowering, the bees were observed to be thoroughly working the mass of flowers. The hives were removed on 23 October, by which time the main flowering period was over, and an adequate setting of seed had been obtained.

The seed pods were harvested in early January, 1954. Seed was harvested separately from each plant, and in the case of the potted plants, the seed was threshed, cleaned, and weighed separately. The seed harvested from the second cell containing the transplanted plants was threshed and cleaned as a bulk sample.

RESULTS AND DISCUSSION

The total amount of clean seed obtained from the two cells (80 plants) was 2.69 lb., with a germination figure of 97%. There was a considerable difference in the yield of seed from individual plants. This fact has been noted on previous occasions at the Crop Research Division

with plants seeding outdoors or under cages. It would be interesting, however, to investigate whether the relative position of individual plants to the hive bore any relation to their yield.

From these preliminary investigations, it has been found that the honey-bee technique is a practical method whereby nucleus seed can be obtained from selected cruciferous plants in glasshouses. Temperature control and shading of the glass are both important factors, and further investigation is necessary to reduce the mortality rate of the bees. One nucleus hive per 40 plants would probably be sufficient.

ACKNOWLEDGEMENT

Acknowledgement is made to Mr. F. A. Bartram, Apiary Instructor, Department of Agriculture, Christchurch, for arranging the hiring of the hives, and for his assistance and advice throughout the investigation.

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PASTURE MANAGEMENT TRIALS ON UNPLOUGHABLE HILL COUNTRY AT TE AWA

I. ESTABLISHMENT OF EXPERIMENTAL AREA AND RESULTS FOR 1949–51

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Summary

Results of trials involving oversowing, topdressing, and different management practices on steep hill country, with a carrying capacity of about 1.5 ewes per acre, are presented for the three years following establishment. Improvement has been measured in terms of ground cover, herbage yields by frame measurements, change in botanical composition by both point analysis and herbage dissection methods, and stock carrying capacity.

Introduction

In 1945, the Soil Conservation and Rivers Control Council, operating through the Manawatu Catchment Board, leased 50 acres of land at Te Awa, Pohangina County, in order to study methods for controlling the severe erosion taking place on an area of about 60,000 acres. The results during the first two years, when the area was under the type of management common to the district, made it obvious that further information was urgently needed on methods for improving hill country pasture associations and on the effect of this improvement on soil stability. To that end a further 130 acres was acquired in 1948, and a series of different treatments and management practices applied.

The results of the work on erosion control have already been published (Suckling, 1950). In this paper the design and layout of the experimental area are described, and the results of the first three years of the trial presented.

Much pasture research has been undertaken on the lowlands in New Zealand but to date very little factual information has been obtained from hill pastures, from the point of view of either management or soil conservation. It was realised that overseas methods of conservation could not be directly applied to New Zealand hill country because of the differences in topography, climate, and pasture utilisation.

The first line of attack in the absence of forest as the most satisfactory soil conservation association was to study in detail our pastures as such, their behaviour under varying management systems, their composition, and their ability to prevent soil loss and retard runoff. Most of our hill country has already been cleared of forest and sown to grass. Over the years, these pastures have generally declined in productivity and deteriorated in effectiveness as a protective cover. It is an open question whether pasture improvement or reforestation offers the best prospects for soil conservation. There is urgent need for more information on the potentialities for improvement of hill pastures from both the farming and soil conservation points of view. Research at Te Awa has been directed towards supplying this information.

In the early stages of the work the main emphasis was on improving the productivity of the pastures, because it was held that if conservation practices could be developed which are consistent with increased production, they would be more beneficial and more readily adopted by the farmer.

Soil Type and Topography

The district in which the Te Awa research area is situated is typical of some 34,000 acres of moderately steep to steep hill country. This area is a small part of the extensive Wanganui peneplain and consists of Castlecliffian marine sands laid down in very shallow water adjacent to a coast line. In the main they consist of coarse unconsolidated quartz sands.

The present topography, following geological uplift and subsequent erosion, is closely and deeply dissected, and gradually rises from 700 ft. in the south to 1,800 ft. in the north. The highest point on the research area is approximately 1,100 ft. The soil types are Raumai sandy loam (11 H) on the easy slopes and hilltops, and Pohangina sandy loam (118a) on the steep hillsides. They are described as hill soils derived from parent sandstone. The soil profile is "5 in. dark-greyish-brown sandy loam, 9 in. pale-brownish-grey sandy loam, mottled, on compact sands" (N.Z. Soil Bureau 1954.).

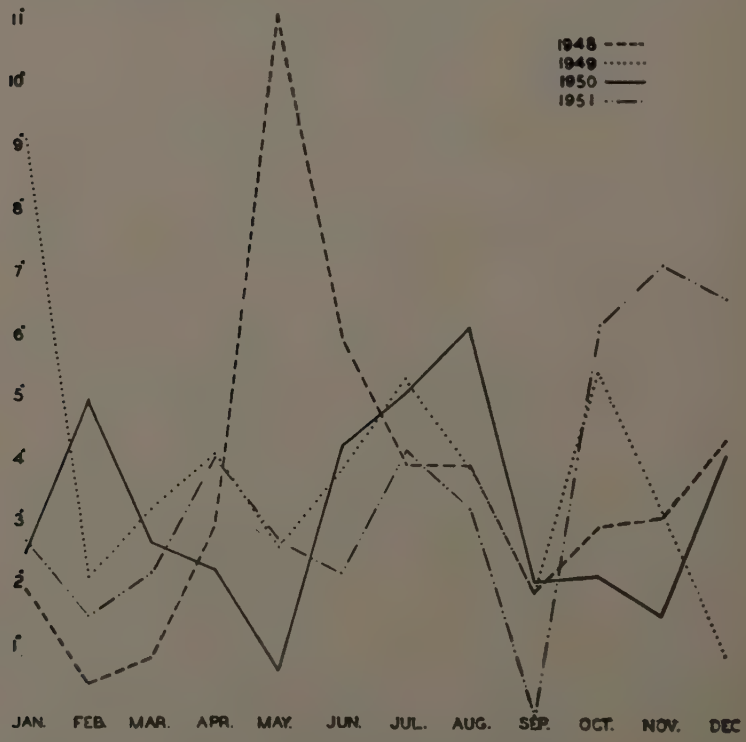

Fig. 1.—Distribution of rainfall during 1948-51.

Climate

The annual rainfall at Te Awa in 1948, 1949, 1950, and 1951 was 43.8, 48.1, 39.4, and 43.8 in. respectively. This rainfall is fairly evenly distributed throughout the year (Fig. 1) but frequent periods of intense rainfall occur during the summer months. Past local experience has indicated that thunder storms in summer have largely contributed to erosion of the district; rainfall intensities of 3 in. per hour have been recorded. During the winter months rainfall is evenly spread and pastures are easily pugged by heavy stock.

In March 1949, thermometers were installed on a flat hill top on the area, for recording earth temperatures at depths of 4 in. and

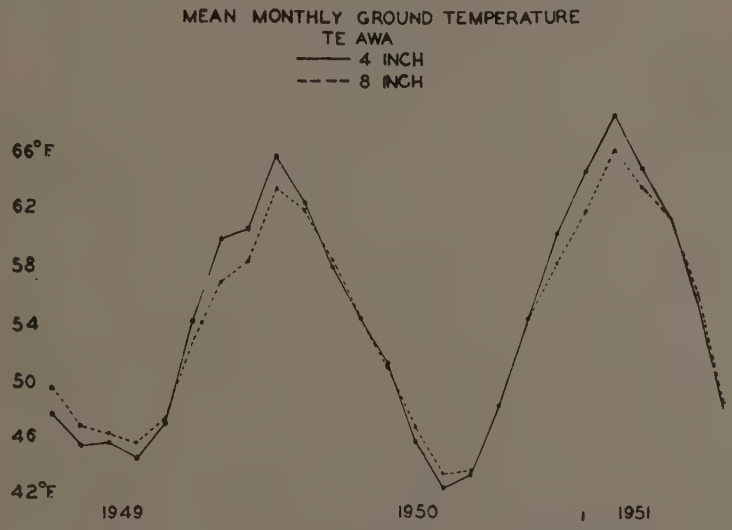

Fig. 2.—Variation in soil temperature at 4 in. and 8 in.

8 in. (Fig. 2). Two additional 4 in. thermometers were installed in October 1949 to record differences in earth temperature between a sunny and shady slope on sites approximately 100 yards apart on either side of a ridge running east and west. Records to date show a difference of approximately 4° between the different aspects (Fig. 3); the temperature of the shady slope has been consistently lower than that of the sunny slope. Frosts are frequent in the gullies and often severe, and there are occasional light falls of snow. Shady faces are frequently coated with frost throughout the whole day and often for several days. Winds are usually strong and mainly from a westerly direction, making the tops bleak and windswept during the winter months.

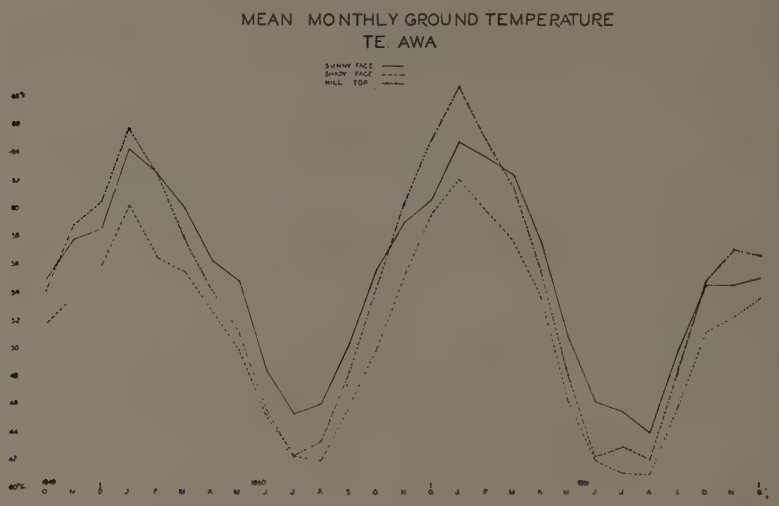

Fig. 3.—Relationship between earth temperatures at 4 in. on hilltop, shady face, and sunny face.

HISTORY OF LAND USE

The original bush, comprising heavy stands of totara, rata, rimu, matai, maire, and hinau, was felled and burnt in the 1880's. Pasture mixtures were sown on the ash from the bush burn. Seeds mixtures used in the district varied, but generally contained some ryegrass, dogstail, cocksfoot, browntop, and white clover. On the Te Awa area, Chewings fescue was also sown and the farmer, like others in the district, harvested Chewings fescue as well as cocksfoot and dogstail seed.

In the early days of seed harvesting on the hills, good yields were achieved owing to the natural fertility of the forest litter which had been built up over many years, and cocksfoot stands were stated to be 3 to 4 ft. high at harvest. With low stocking rates and with no addition of fertilizer, the inherent fertility rapidly diminished and the cover began to revert to bracken and scrub. In order to keep the secondary growth under control, the land was occasionally heavily stocked with cattle. In more recent years, heavier stocking with sheep was practised, but the pastures continued to deteriorate and the carrying capacity to diminish. Species such as cocksfoot have gradually been eaten out under hard close grazing. The poor strains of ryegrass and clovers rapidly disappeared, leaving a clover-deficient pasture dominated by browntop, *Danthonia*, Yorkshire fog, and weeds. This clover deficiency was also induced by the smother due to light grazing of pastures early in the district's development.

RESEARCH PROGRAMME

The area was subdivided in 1948 into 10-acre paddocks (Fig. 4) and investigations were started to determine what system of grazing management would give both maximum production and maximum

spread of production throughout the year. The following practices were compared: (a) oversowing with seed, (b) topdressing, (c) periodic spelling, (d) different stocking rates, and (e) different systems of grazing, particularly set stocking and rotational grazing.

MANAGEMENT TRIALS

The grazing treatments and initial carrying capacities are shown in Table 1.

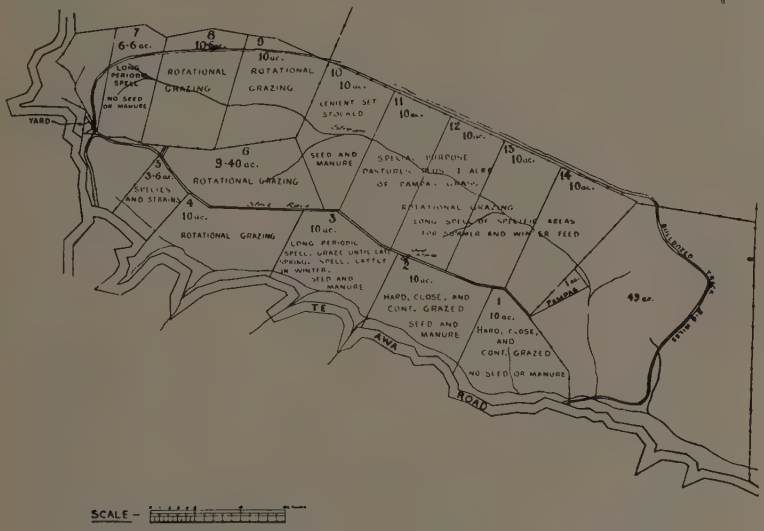

Fig. 4.—Layout and subdivision of the 180-acre area for the years 1948-51. Scale 1 in. = 15 ch.

Preparatory Work

Fencing and Tracks

Approximately 4 miles of fencing were completed by July 1948. A race was fenced off and gates were installed so that the small flocks of sheep could be brought in to the yards without passing through paddocks subjected to other treatments.

Approximately 2½ miles of bulldozed access track was formed between January and April 1948, and the resultant 8 acres of bare track, fill, and embankment, were sown in mid April 1948 with the following seeds mixture:

	lb. per acre
Certified N.Z. perennial ryegrass	10
Certified N.Z. Italian ryegrass	10
Certified N.Z. short-rotation ryegrass	10
Certified N.Z. white clover	2
Browntop	2
Subterranean clover: Mt. Barker	1
Tallarook	1
Lotus major	1
Crested dogstail	4
	41

TABLE 1. STOCK NUMBERS AND GRAZING TREATMENTS

Paddock	Area (ac.)	Stock	Grazing treatment
1	10	20 ewes	Heavy set stocking to winter capacity —no seed or manure.
2	10	16 ewes	Heavy set stocking to winter capacity —seed and manure.
3	10	16 ewes	Long periodic spell—seed and manure.
4, 6, 8, 9	40	64 ewes	Rotationally grazed—seed and manure.
5	3.6	6 ewes	Set stocked—species and strain trials etc.
7	6.6	10 ewes	Long periodic spell—no seed or manure.
10	10	15 ewes	Lenient set stocked—seed and manure.
11, 12, 13, 14	40	64 ewes	Rotationally grazed with long spell of specific areas for summer and winter feed—seed and manure and special-purpose pasture mixture on paddocks 11 and 14.
15	50	Varied	Under farmers management.

Heavy rain fell after the completion of the work, particularly during May. This caused a considerable amount of slipping of the banks in the deeper cuttings. Runnelling occurred in the surface of the track and in the water tables against the banks, often undermining the toes and causing slips (Fig. 5). Bulldozing added to the general instability by shattering the profiles in the "cut" areas.

Various methods were tried to prevent further scouring of the steeper slopes. The deeper runnels were filled with manuka; rushes were used in some cases with satisfactory results; the smaller rills were effectively checked by making small dams with rush sods at intervals down the length of the rill. The most satisfactory method of capturing the storm water and preventing scour was to cut shallow trenches across the road surface; on the steeper sections of the road it was found necessary to have these shallow drains every half chain down the slope. A considerable amount of track maintenance was required throughout the period and particularly during the first six months. Most of the track is now grassed, but sheep and cattle camp on the surface and tramp out sections near gate-ways. Attempts at regrassing these small areas have failed in this soft sandy soil because heavy tramping by stock ruins the strike before the grass has been properly established. Periodic attention is still given to the shallow cut-off drains throughout the length of the track, particularly on the steeper slopes, and some trees were planted on the banks and slopes during the winter months of 1951 to give additional stability.

Sheds and Yards

A set of yards and a weighing shed were constructed on the site shown in Fig. 4, being completed by the end of September 1948.

Fig. 5.—Scouring and slipping on bulldozed tracks, following heavy rain shortly after completion.

Stock Dams

The supply of water became a problem as soon as the area was subdivided. Before this, water was available from the gully running through the length of the area where small pools remained filled with water over most of the year. With the new experimental layout, several paddocks, particularly those composed entirely of sunny faces, were without water.

To overcome this difficulty nine ponds were excavated, four with a bulldozer and the remaining five with horses or tractor and hand-controlled scoop.

In all cases some time elapsed before the dams retained water. However, they sealed up sufficiently well to provide a valuable supply during the following summer.

A few points of interest have arisen from the experience gained in constructing these dams, which are listed herewith.

Dams should be constructed in places with restricted catchment areas to avoid silting. Through force of circumstances two dams were

constructed in Paddock 1 in positions that collect rainfall from fairly large areas. Both of these ponds silted up so rapidly that they no longer hold water.

The most satisfactory dams are on almost flat ground; these have not silted although ample water has been stored.

In all cases overflow channels were directed over undisturbed turf with satisfactory results; there has been no scouring in spite of heavy rain, except where water flowed over the embankment before consolidation and regrassing had taken place.

Pasture Improvement

Oversowing

The most noticeable feature of most New Zealand hill country pastures is the lack of highly productive clovers, and the Te Awa area was no exception. Since lack of nitrogen is the major factor limiting pasture production, the introduction of clovers of good strain was essential, and the paddocks included in the improvement programme were oversown during March and April 1949.

Experiments over a wide range of soil types and climatic conditions have shown that, almost without exception, white, red, and subterranean clover, and *Lotus major*, established better when sown in March than when sown in April or May, and much better than when sown in August to October (Table 2).

TABLE 2. EFFECT OF DATE OF SOWING ON THE STRIKE OF DIFFERENT SPECIES

(Seedling establishment as percentage of viable seed sown, average of figures from 5 trial areas.)

Month of Sowing	Percentage strike of seed sown			
	Red clover	White clover	*Lotus major*	Subterranean clover
March	30	27	15	82
April	25	22	8	47
May	3	5	1	2
August	6	11	3	4
September	9	8	1	10
October	13	11	2	7

Although on the 50-acre block there had been virtually no establishment of oversown grasses, complex seeds mixtures containing grass species were again used on paddocks 2, 3, 4, 5, 6, 8, 9, 10, 12, and 13 (a total of 93.6 acres). The mixture comprises 10 lb. perennial ryegrass, 3 lb. crested dogstail, 2 lb. Montgomery red clover, 2 lb. broad red clover, 2 lb. certified white clover, 1 lb. Mt. Barker subterranean clover, 1 lb. Tallarook subterranean clover, and ½ lb. *Lotus major* per acre. Paddock 14, designed to provide special summer feed, was sown with a mixture similar to the above, with addition of 4 lb. *Paspalum dilatatum* (spring

sown), 1 lb. strawberry clover, 1 lb. Montgomery and 1 lb. broad red clover, and ½ lb. *Lotus major* per acre. Paddock 11, designed to provide special winter feed, was sown with the general base mixture plus 15 lb. short-rotation ryegrass, 4 lb. Yorkshire fog, and 2 lb. *Phalaris tuberosa* per acre.

The high rainfall of the summer of 1948–49 caused an abnormal flush of growth in January, February, and March, and difficulty was experienced in grazing the pastures sufficiently hard to provide good conditions for oversowing. A large mob of sheep and cattle was grazed from paddock to paddock, and the sward bared as much as possible. On the rotational grazing areas, where paddocks comprised both sunny and shady faces, the tendency for the grazing animals to congregate on the warm sunny faces resulted in those pastures becoming satisfactorily grazed while the shady faces were neglected almost completely. Repeated attempts at driving stock on to the shady slopes were unsuccessful, with the result that the strike of sown clovers was poorer than on the sunny slopes. As each paddock was grazed it was sown down, the first being sown on 16 April, 1949, but the process took so long that the last paddock was not sown till 20 April. This was 2 to 3 weeks later than the optimum time for oversowing (Suckling 1949).

Establishment

Establishment counts were made two months after oversowing and again two months later. One hundred quadrats, each of one square foot, were taken at random on each oversown paddock during May and July. Table 3 presents a small but representative selection of the results obtained, grouped both according to aspect and to management. Only the figures for clovers are given, since again there was no indication that any grass seed established.

The Table indicates quite clearly (and this is borne out by close observation over the whole area) that establishment is best where the pasture is closely grazed prior to oversowing. It also shows that results are better on sunny than on shady slopes, a natural consequence of the difficulty of cleaning moss and rank growth from the latter. Had it been possible, as it was later, to graze the two aspects independently, there is no doubt that a better strike on shady slopes would have been achieved.

Percentage strikes were calculated on the basis that the numbers of seeds sown per square foot were 11 of broad red clover, 11 of Montgomery red clover, 15 of white, 2¾ of subterranean clover, and 10⅓ of *Lotus major*. The Table emphasises that even where conditions for oversowing approach the ideal the effectiveness of the operation is very low. It also clearly demonstrates the losses that occur during the seedling stage.

It will be appreciated that, owing to the failure of the grass species, the special-purpose pastures hardly justified this title. On the other hand the extra red clover and *Lotus major* sown on the summer-spelled paddocks were beneficial. The sowing of strawberry clover was virtually a failure.

Topdressing

Considerable emphasis has been laid on the importance of phosphate application at the time of over-sowing. However, trials have shown that such application has had no significant effect on the early

TABLE 3. ESTABLISHMENT COUNTS, TE AWA 1949

Average number of plants established per square foot and approximate percentage of seed sown

Location of Quadrats and Treatment	Length of time after sowing	Species							
		Red clover		White clover		Sub. clover		*Lotus major*	
		No.	%	No.	%	No.	%	No.	%
Paddocks 2, 3, 5, 10 Sunny face, set stocked	2 months	1.62	7.4	1.18	7.9	0.27	9.8	0.06	0.6
	4 months	0.56	2.5	0.13	0.9	0.41	14.9	0.03	0.3
Paddock 10 Shady face, set stocked	2 months	0.33	1.5	0.44	3.0	0.54	19.7	0.20	2.0
	4 months	0.20	0.9	0.40	2.7	0.25	9.0	0.10	1.0
Paddocks 4, 6, 8, 9, 11, 12, 13 Sunny face, rotational grazing	2 months	0.65	3.0	0.39	2.6	0.40	14.5	0.03	0.3
	4 months	0.34	1.5	0.29	2.0	0.47	17.0	0.04	0.4
Paddocks 8, 9, 11, 12, 13 Shady face, rotational grazing	2 months	0.25	1.0	0.23	1.5	0.1	3.6	0.05	0.5
	4 months	0.20	0.9	0.25	1.7	0.2	7.3	0.07	0.7
Overall average	2 months	0.71	3.2	0.52	3.5	0.26	9.4	0.05	0.5
	4 months	0.35	1.6	0.25	1.7	0.36	13.1	0.04	0.4

establishment of clovers, and that topdressing with phosphates is not essential until the seedling plants are established and are able to give a return for the additional phosphate. The situation may be different on soils extremely deficient in phosphate.

Shortly after oversowing was completed, the sown areas were topdressed with 2 cwt. per acre of superphosphate. In each of the ensuing two years the area was topdressed in the autumn with the same quantity of fertilizer, making a total of 6 cwt. per acre over the period 1949–51.

Treatment after Sowing

Close continuous grazing after sowing was found to be superior to rotational or intermittent grazing. There were indications that where pasture is vigorous in growth during the autumn months long spelling has a detrimental effect (Sears 1950) as the smaller seedlings were smothered by fast-growing grass species. Subterranean clover showed the highest survival rate, but subsequent grazing caused losses of this species owing to complete defoliation of plants drawn up with the long grass.

Natural Reseeding

Four relatively steep 10-acre paddocks were managed differentially to determine the extent of natural reseeding in close-grazed pastures compared with those that had been spelled to allow them to reseed more freely.

The treatments were:

Paddock 1 Continuously close-grazed with no application of seed or fertiliser.

Paddock 2 Continuously close-grazed with seed and fertilizer added.

Paddock 3 Continuously close-grazed with seed and fertiliser added, but spelled in summer to allow reseeding.

Paddock 7 Continuously close-grazed with no seed or fertiliser added, but spelled in summer to allow reseeding.

In August 1950 and 1951, after the autumn germination of seed shed the previous season, random soil samples for counts of buried clover seed were taken to a depth of 2 in. from stock camps, slopes, and steep faces, and terraces or stock tracks (Hyde and Suckling 1952).

Table 4 gives a comparison of buried-seed content of pastures under various management systems for the years 1950 and 1951. It will be seen that:

Continuous close grazing of the two oversown and topdressed pastures does not allow white clover, red clover, or *Lotus major* to re-seed.

Continuous close grazing does not prevent subterranean clover from reseeding.

Oversown and topdressed pastures that have been spelled to allow them to reseed show great increases in the amount of hard seed of all clover species present. In lb. per acre of hard seed, the figures are: white clover 28, red clover 1, subterranean clover 7, suckling clover 77, *Lotus major* 3⅔, and English trefoil 1.

TABLE 4. AMOUNT OF BURIED CLOVER SEED IN HILL PASTURES UNDER VARIOUS TREATMENTS

Treatment	Month and Year	Location of Sample	Clover seeds per sq. ft. in top 2 in. of soil					
			White	Red	Suckling	Subterranean	*Lotus major*	English trefoil
Paddock 1								
(a) Continuous close grazing no seed or manure.	August 1950	Slopes	0	0	270	0	0	0
		Tracks	0	0	380	0	0	0
		Stock camp	30	0	150	0	0	0
		Average	**10**	**0**	**266**	**0**	**0**	**0**
(b) Continuous close grazing no seed or manure.	August 1951	Slopes	5	0	300	0	0	0
		Tracks	0	0	290	0	0	0
		Stock camp	30	0	130	0	0	0
		Average	**12**	**0**	**240**	**0**	**0**	**0**
Paddock 2								
(a) Continuous close grazing + seed and manure.*	August 1950	Slopes	20	0	385	0	0	0
		Tracks	5	0	340	0	0	0
		Stock camp	10	0	100	0	0	0
		Average	**12**	**0**	**275**	**0**	**0**	**0**
(b) Continuous close grazing + seed and manure.*	August 1951	Slopes	10	0	270	40	0	0
		Tracks	20	0	290	0	0	10
		Stock camp	0	0	160	20	0	0
		Average	**10**	**0**	**240**	**20**	**0**	**3**
Paddock 3								
(a) Continuous grazing + seed and manure* with periodic spell for reseeding. Before spelling.	August 1950	Slopes	10	0	250	0	0	0
		Tracks	10	0	430	0	0	0
		Stock camp	10	0	140	0	0	0
		Average	**10**	**0**	**307**	**0**	**0**	**0**
(b) Continuous grazing + seed and manure* with periodic spell for reseeding. After spelling.	August 1951	Slopes	240	10	1,900	20	120	0
		Tracks	815	15	2,190	45	95	5
		Stock camp	680	10	410	0	80	25
		Average	**578**	**12**	**1,500**	**22**	**68**	**10**
Paddock 7								
(a) Continuous grazing, no seed or manure, with periodic spell. Before spelling.	August 1950	Slopes	0	0	180	0	0	0
		Tracks	0	0	360	0	0	0
		Stock camp	10	0	190	0	0	0
		Average	**3**	**0**	**243**	**0**	**0**	**0**
(b) Continuous grazing, no seed or manure, with periodic spell. After spelling.	August 1951	Slopes	10	0	140	0	0	10
		Tracks	50	0	450	0	0	0
		Stock camp	90	0	690	0	0	0
		Average	**50**	**0**	**427**	**0**	**0**	**3**

*Sown autumn 1949

In spelled pastures that have not received additional clover seed or fertilisers, there is an increase in buried seed of white clover and also of suckling clover and English trefoil. However, the fact that the white clover on the area was of poor type detracted from the improvement that could be expected.

Dissemination of Seed by Stock

Suckling (1952) pointed out that the ability of stock to disseminate seed on hill country could be exploited. The impermeable seed coat of clover seed not only enables it to survive passage through the animal but also spreads its germination over a long period of time. Under the unfavourable conditions frequently encountered on hill country, there is some advantage in having seed germinate over a long period rather than all together as soon as temperature and moisture are favourable.

For these reasons, determinations were made of the quantities of hard seed being returned to spelled pastures. Fifty random samples of cow dung were taken from each of the two spelled pastures at the time when all seeding clover had been eaten by stock.

Seed was extracted from a representative sample of dung from the two paddocks, and Table 5 shows the quantities of seed per lb. of dung returned to the soil. As the seed that passes through the animal is largely hard seed, it is reasonable to assume that this seed will germinate over a long period, thus ensuring a continuity of clover, particularly of species not able to reseed when closely grazed.

TABLE 5. SEED CONTENT OF COW DUNG FROM SPELLED PASTURES

Species of Clover	Seeds per lb. of dung		lb. of seed per acre*	
	Paddock 7 Not oversown	Paddock 3 Oversown	Paddock 7 Not oversown	Paddock 3 Oversown
White	350	1,775	0.8	4.5
Red	—	115	—	0.5
Subterranean	—	130	—	2.0
Lotus major	—	480	—	1.0
Lotus hispidus	—	20	—	0.1
Suckling	59	910	0.1	2.0
English trefoil	5	110	0.02	0.5
Totals	414	3,540	0.92	10.6

*Calculated on basis of 40 lb. of dung per cow per day.

Tables 4 and 5 show that it is possible, through summer spelling, to achieve a rapid build up of clover seed in the soil. It may be that species such as red clover, that are rapidly eaten out of a pasture when close grazed, can be perpetuated indefinitely. The small quantity of clover sown initially is handsomely increased by spelling, with little cost and great satisfaction to the farmer (Fig. 6). The best time to spell paddocks is after the spring flush of growth and when the bulk of rough-

Fig. 6.—Oversown pasture, Paddock 3, spelled one month, showing strong growth of white clover.

age and seed head has been consumed by sheep and cattle. In this way the hill farmer can simulate the seed grower who takes a crop of hay and harvests the aftermath of clover for seed.

Insect Damage

In view of the fact that considerable damage to clover seedlings following oversowing has been observed at Te Awa, an investigation was carried out to identify the insect responsible and to measure the density of insect and earthworm populations.

Counts were made on cubic-foot earth samples in May 1951 when the average population was 32 earthworms, 2 *Oxycanus* ("subterranean") caterpillars, 22 grassgrubs (*Costelytra zealandica* (White)), and 0.75 wireworms.

Of these it was considered that *Oxycanus* was primarily responsible for seedling damage. In March the insects are small and are able to eat into the germinating seedling, usually consuming the cotyledons and generally leaving the radicle untouched. Laboratory investigations with *Oxycanus* caterpillars placed in soil on which large numbers of germinat-

ing subterranean clover seedlings were sown, failed to show any insect damage to the seedlings except when the containers were placed in the dark at 20°c. Being nocturnal in feeding habits these insects were difficult to observe. They are also very sensitive to noise and generally difficult to handle in captivity.

In the field the *Oxycanus* caterpillar does greater damage to pasture as it gets larger. Late autumn and early spring sowings are more susceptible to insect damage than early autumn or late spring sowings.

Botanical Composition

Changes in botanical composition as affecting ground cover were measured by the point analysis method, while rate of growth and total dry-matter production were measured by means of frame enclosures. For the former, ten fixed line transects were pegged in each paddock; two on stock camps, two on dry knobs, two on shady faces, two on sunny faces, and two on slip areas. Point analyses were made four times a year, 14,000 points being examined at each analysis.

Table 6 shows the effect of grazing treatment, and of oversowing and topdressing, on pasture composition as determined by the point analysis method. A general improvement in botanical composition of the pastures during the two-year period is indicated.

Effect of Oversowing and Topdressing

Whatever the system of grazing, oversowing and topdressing increased the amount of ryegrass, dogstail, and total clovers, and decreased slightly the amount of bare ground and weeds. A comparison between the untreated and treated pastures, in 1951, shows that ryegrass increased from 3 to 17, crested dogstail from 8 to 16, and total clovers from 8 to 30, while bare ground decreased from 13 to 5. The comparison between Paddocks 1 and 2, both with heavy set stocking, indicates the changes induced by topdressing and oversowing. The areas were comparable at the commencement of the trial in 1948 but large differences were apparent in 1951. On the treated pastures, ryegrass increased from 5 to 19 and dogstail from 12 to 18; browntop was reduced from 38 to 28; total clovers increased from 7 to 30.

In comparing Paddock 3 with Paddock 7, (both of which were periodically spelled and in all respects treated alike, except that Paddock 3 was topdressed and oversown whereas Paddock 7 was not), a marked improvement is seen in Paddock 3, particularly in total clovers. The grasses did not improve to the same extent as in the other closely grazed paddocks because, owing to this spelling, there was not the continued return of dung and urine, which is undoubtedly a major factor in ryegrass improvement on the other close-grazed areas. As shown in Table 6, the grass species remained much the same in both paddocks, but total clovers increased from 8 in Paddock 7 to 45 in Paddock 3.

Spelling allowed the oversown clovers to reseed, with the result that total clovers in Paddock 3 (spelled) were 45 compared with 30 in the non-spelled paddocks. Reference has already been made to the effect on ryegrass, but for emphasis it is repeated here. In Paddock 3 ryegrass showed 9 hits per 100 points and in the unspelled area 17, and dogstail was 4 compared with 16.

TABLE 6. COMPARISONS OF PASTURE COMPOSITION UNDER VARIOUS GRAZING TREATMENTS

Paddock No.	Treatment	Date of Examination	Botanical Composition (Hits per 100 points)																	
			Perennial ryegrass	Cocksfoot	Crested dogstail	Chewings fescue	*Danthonia*	Browntop	Sweet vernal	Yorkshire fog	Red clover	White clover	Suckling clover	Subterranean clover	*Lotus* species	Total clovers	Bare ground	Catsear	Other grasses	Other species
2-14 excl 3 & 7	Oversown pastures	Autumn 1949	10	2	8	12	10	32	15	11	—	4	6	—	Tr	10	8	20	4	7
„ „ „ „	„ „	„ 1951	17	2	16	17	14	30	16	16	1	18	5	4	2	30	5	14	5	9
1 & 7	Not oversown	Autumn 1951	3	3	8	15	14	36	15	13	—	5	3	—	—	8	13	15	2	10
2-14 excl. 3 & 7	Oversown	„ 1951	17	2	16	17	14	30	16	16	1	18	5	4	2	30	5	14	5	9
1	Heavy set stocking, not oversown	Autumn 1951	5	2	12	8	17	38	19	10	—	4	3	—	—	7	12	19	1	8
2	Heavy set stocking, oversown	„ 1951	19	1	18	8	16	28	16	5	1	15	5	7	2	30	9	21	2	6
7	Periodic spell, not oversown	Autumn 1951	2	4	4	23	11	35	12	16	—	6	2	—	—	8	13	11	2	13
3	Periodic spell, oversown	„ 1951	9	3	4	17	13	34	16	7	4	23	13	2	3	45	10	6	10	3
3	Periodic spell, oversown	Autumn 1951	9	3	4	17	13	34	16	7	4	23	13	2	3	45	10	6	10	3
2-14 excl. 3 & 7	Set stocking and rotational grazing, oversown	„ 1951	17	2	16	17	14	30	16	16	1	18	5	4	2	30	5	14	5	9
11	Oversown, autumn spelled	Autumn 1949	10	4	6	12	10	26	31	19	—	3	3	—	—	6	13	37	4	7
„	„ „ „	„ 1951	11	5	13	16	12	35	23	32	Tr	17	3	3	4	27	5	13	3	16
„	„ „ „	Winter 1951	9	3	13	18	11	25	19	30	2	14	6	2	5	29	5	8	3	15
„	„ „ „	Spring 1951	11	2	5	16	18	34	31	38	2	26	17	3	7	55	5	15	4	13
„	„ „ „	Summer 1951	6	2	8	16	9	23	12	22	Tr	13	1	1	3	18	13	10	5	7
14	Oversown, summer spelled	Autumn 1949	10	2	8	4	10	20	15	14	—	2	5	—	Tr	8	18	25	3	6
„	„ „ „	„ 1951	15	1	11	12	19	22	13	18	1	9	12	7	3	33	10	10	7	8
„	„ „ „	Winter 1951	10	3	11	12	18	23	13	18	Tr	9	20	8	2	40	7	6	6	7
„	„ „ „	Spring 1951	12	2	13	12	23	29	24	26	5	15	39	10	6	75	3	17	10	9
„	„ „ „	Summer 1951	6	1	9	10	12	14	6	19	Tr	7	2	4	2	15	24	9	Tr	3

Fig. 7.—Red and white clover with *Lotus major* reseeding in spelled pasture.

Effect of Spelling

As Paddock 11 was spelled each autumn for winter feed, records have been kept of the effect on pasture composition of this practice. The table shows slightly more ryegrass in spring and autumn than in summer or winter. Cocksfoot makes its main contribution in the autumn. The main feature, however, was the great increase in Yorkshire fog, for which 19 hits were recorded in autumn 1949, compared with 32 in 1951. This species produces a good bulk of feed during the winter months, and has proved to be a valuable plant. Total clovers increased from 6 in 1949 to 27 in 1951 (Fig. 7).

In Paddock 14, which was spelled for a short period in summer each year, ryegrass increased from 10 to 15 over the 3 years, dogstail from 8 to 11, and total clovers from 8 to 33. This treatment favours the clovers, but the spell of 3 months—December to March—does not allow red clover to reseed satisfactorily.

Effect of Site

In Table 7 the fixed line transects are grouped according to site and afford a more detailed comparison of pasture composition in 1949 and 1951 on both improved and unimproved pasture.

TABLE 7. PASTURE COMPOSITION ON

Site	Ryegrass		Dogstail		Cocksfoot		Chewings fescue		*Danthonia*		Browntop		Sweet vernal		Yorkshire fog	
	1949	1951	1949	1951	1949	1951	1949	1951	1949	1951	1949	1951	1949	1951	1949	1951
1. Slips Unsown Paddocks	—	—	—	—	—	—	2	3	—	9	14	17	12	17	1	1
2. Slips Sown Paddocks	2	3	3	9	1	1	2	12	5	11	20	25	13	22	8	15
3. Stock camps Unsown Paddocks	31	24	3	13	3	2	—	1	2	—	19	47	16	10	24	21
4. Stock camps Sown Paddocks	49	67	10	8	2	2	2	8	1	1	25	25	14	8	21	27
5. Easy slopes Unsown Paddocks	1	1	3	5	1	7	42	12	8	25	31	45	37	16	4	13
6. Easy slopes Sown Paddocks	3	11	16	22	2	2	17	20	8	15	44	44	16	14	10	15
7. Sunny faces Unsown Paddocks	5	—	4	6	6	3	1	1	2	20	17	30	32	18	14	20
8. Sunny faces Sown Paddocks	3	9	13	19	3	3	13	23	12	16	41	36	17	14	9	17
9. Shady faces Unsown Paddocks	1	2	3	3	—	7	30	28	—	6	34	41	11	12	24	16
10. Shady faces Sown Paddocks	1	5	10	17	2	3	14	23	11	10	35	40	18	17	17	31

The slips on the unsown paddocks did not improve to any marked extent over the three-year period apart from a slight increase in ground cover from volunteer grasses.

The slips on the sown paddocks, although originally slightly better in ground cover than the slips on the unsown areas, improved in clover content. Total clovers on the slips were 7 in 1949 and 30 in 1951. Both bare ground and moss had been reduced over the period.

The stock camps on the unsown areas showed a reduction in ryegrass content and an increase in browntop and white clover. These changes were probably brought about by the spelling of Paddock 7 which allowed a certain amount of reseeding of the volunteer white clover. Browntop was also favoured by this management.

In the paddocks that were oversown and topdressed, the original analyses followed the sowing and topdressing, hence the higher ryegrass figure in the original analyses. However, there has been a marked increase in ryegrass since 1949 and also in white clover. Subterranean clover has not done well on the stock camps where fertility was high and

VARIOUS SITES, IN 1949 AND 1951

Other grasses		Red clover		White clover		Suckling clover		Sub. clover		*Lotus* species		Other species		Bare ground		Moss		Catsear	
1949	1951	1949	1951	1949	1951	1949	1951	1949	1951	1949	1951	1949	1951	1949	1951	1949	1951	1949	1951
—	—	—	—	—	—	—	—	—	—	—	—	17	23	32	28	23	23	8	5
11	3	—	1	2	14	5	5	—	7	—	3	2	6	30	12	37	12	12	14
5	1	—	—	7	12	1	2	—	—	—	—	5	3	—	—	—	—	15	15
—	—	—	1	8	35	1	1	—	1	—	—	7	3	1	3	—	—	12	5
2	1	—	—	2	3	5	4	—	—	—	—	9	2	3	7	—	—	23	25
—	—	—	1	2	17	7	7	—	3	—	3	8	9	2	1	2	3	25	20
3	1	—	—	1	8	1	3	—	—	—	—	1	2	15	22	3	15	13	17
1	3	—	1	3	15	6	8	—	3	—	1	4	3	3	4	1	2	26	18
1	—	—	—	27	18	3	1	—	—	—	—	7	3	—	14	—	—	21	13
1	1	—	1	2	14	3	5	—	4	—	1	2	5	6	3	12	11	13	9

competition from ryegrass and white clover was severe. *Lotus major* did not establish on the stock camps, probably also because of competition.

The pasture composition on the easy slopes on the unsown paddocks has remained much as in 1949 except for decreases in Chewings fescue and sweet vernal. The periodic spelling has probably been responsible for these differences.

The improvement on the easy slopes of the oversown and topdressed paddocks is shown in the increase of ryegrass and dogstail, and the increase of total clovers from 9 to 30.

Effect of Aspect

The sunny faces on the unsown areas showed a reduction in ryegrass and sweet vernal, but a slight increase in white clover following the summer spelling and natural reseeding. *Danthonia* increased considerably over the three-year period.

On the treated sunny faces there was an increase in ryegrass and dogstail and a slight reduction in browntop. Yorkshire fog increased

Fig. 8.—Frame enclosures for measurement of herbage production.

with the rise in fertility and the total clovers rose from 9 to 28. There was a slight reduction in flat weeds.

On the shady faces on the untreated paddocks browntop increased slightly but Yorkshire fog decreased; white clover decreased from 27 to 18, and flat weeds from 21 to 13.

Ryegrass, dogstail, Chewings fescue, and Yorkshire fog increased on the shady faces of the treated paddock. White clover increased from 2 to 14 with some red and subterranean clover making an appearance. *Lotus major* established very slowly, but a great improvement in ground cover of this species may be expected in the next few years.

Herbage Production

For measurement of production three frames were placed in each paddock in November 1948 (Fig. 8). Wherever practicable they were cut monthly and then moved on to a different location. In the rotationally grazed areas, frames were cut at every second rotation of the sheep, i.e., at intervals of 21 days. During the winter months when growth slowed down, monthly cuts were made and in some cases, where no growth was evident, the frames were shifted and a nil return recorded.

TABLE 8. HERBAGE PRODUCTION AND COMPOSITION, NOVEMBER 1948 TO NOVEMBER 1950

Paddock No.		Dry Matter		Crude Protein		Botanical Composition % of D.M.				Botanical Constituents lb. of D.M. per acre			
		lb. per acre	Per cent	% of D.M.	lb. per acre	Ryegrass and Dogstail	Other Grasses	Clovers	Other Species	Ryegrass and Dogstail	Other Grasses	Clovers	Other Species
1	*A	5174	24.7	14.9	771	22	62	3	13	1138	3207	155	674
	B	4093	27.9	12.0	490	17	55	4	24	696	2251	164	982
2	A	6503	26.5	11.7	760	22	60	2	16	1431	3902	130	1040
	B	7929	22.8	15.7	1246	27	46	16	11	2141	3647	1269	872
3	A	7677	31.0	10.0	767	18	71	2	9	1382	5451	154	690
	B	5840	30.3	13.8	571	15	50	13	22	622	2074	539	912
4	A	8769	28.7	11.4	999	19	71	1	9	1666	6226	88	789
	B	5728	24.3	13.9	798	18	58	17	7	1031	3222	974	401
5	A	8693	25.8	13.8	1192	20	66	5	9	1739	5737	435	782
	B	7195	22.3	15.2	1093	27	54	14	5	1943	3885	1007	360
6	A	8949	25.2	12.9	1154	23	66	2	9	2058	5906	179	806
	B	6529	24.7	13.2	860	15	69	11	5	979	4506	718	326
7	A	3615	34.9	12.5	452	1	90	—	9	36	3253	—	326
	B	5050	32.5	12.7	643	3	86	4	7	152	4342	202	354
8	A	8923	26.9	9.6	859	16	70	2	12	1428	6246	178	1071
	B	6177	26.7	13.4	826	10	66	17	7	618	4077	1050	432
9	A	8859	25.8	12.2	1080	22	60	2	16	1949	5316	177	1417
	B	6548	24.9	13.5	958	16	60	16	8	1048	3928	1048	524
10	A	8378	26.1	13.0	1089	16	64	5	15	1340	5362	419	1257
	B	5532	24.3	14.6	856	13	56	23	8	719	3098	1272	443
11	A	10103	25.7	10.9	1101	14	68	6	12	1414	6870	606	1212
	B	6672	24.5	13.7	916	15	71	11	3	1001	4737	734	200
12	A	8551	26.7	11.9	1018	19	71	3	7	1625	6072	257	599
	B	7723	21.7	15.6	1208	19	54	20	7	1467	4170	1545	541
13	A	9815	26.2	12.6	1237	20	58	7	15	1963	5693	687	1472
	B	5430	24.3	15.1	819	14	52	29	5	760	2823	1575	272
14	A	9445	26.9	14.3	1351	17	73	4	6	1605	6895	378	567
	B	4960	24.2	14.7	730	11	70	14	5	546	694	248	248

*A, November 1948 to November 1949: B, November 1949 to November 1950.

Where paddocks were spelled periodically, the frames were cut when the stock were taken off after having grazed the spelled pasture.

The herbage was weighed and sampled for determination of botanical composition and dry weight. Samples of the dried material were ground and stored. Every three months the accumulated samples were bulked and aliquots were analysed for protein content.

Table 8 shows the levels of production on all treatments and the contribution of various species to total yield. In all paddocks except Paddock 2, production was greater in 1948–49 than in 1949–50.

The winter-spelled Paddock 11 produced greater bulk of feed over the two years than any other paddock. A large proportion of this was due to the strong growth of Yorkshire fog during the winter months. Although Yorkshire fog is unpalatable in summer, the ewes appeared to relish the 6 to 8 in. dominantly fog pasture during August of each year.

The table gives an additional measure of the increase in ryegrass, crested dogstail, and total clovers, in the improved pastures over those that had not been topdressed or oversown. In all paddocks the clovers increased during the 1949–50 season even though the total grass growth was lower than for the previous year.

Further subdivision was carried out during 1951 and, as a result, there were not enough frames. The data for 1951 are therefore incomplete.

Correlation of Pasture Production with Carrying Capacity

It is difficult from the records to assess the feed requirements of animals on the hills, for several factors militate against accuracy in the measurement of feed produced and stock carried.

The efficiency of pasture sampling was low. Each paddock comprised different micro-environments depending on aspect, steepness, soil moisture, fertility, and plant cover. On stock camps, herbage production was equivalent to 9,000 to 14,000 lb. of dry matter per acre per annum, whereas the recent slips produced little or nothing. In such a mosaic the use of only three 4 × 10 ft. cages to measure the production from a ten-acre paddock would lead to great errors. It is planned to improve the accuracy of pasture production measurements in two ways—by increasing the number of cages used, and by surveying the areas of the barren slips.

It was impracticable to measure the amount of feed consumed by the cattle that were occasionally grazed on the experimental area. There were no facilities for weighing cattle and therefore the gain or loss of condition could not be ascertained.

The number of cattle days was recorded, and in assessing the carrying capacity of each paddock it was assumed that a cattle beast is equivalent to five ewes. Lambs were not taken into account until they were weaned.

Over the four-year period 1946–50, the average amount of dry matter produced for each ewe carried was approximately 2,000 lb. per annum.

Effect of Subdivision on Carrying Capacity

In 1946, the 50-acre paddock (Fig. 4) was fenced from a paddock of approximately 200 acres, and in the first 12 months its carrying capacity had risen from approximately 2 to 2.6 ewe-equivalents. This effect was obvious before any improvement had been felt from the oversowing of clover species, and it is probable that subdivision with the consequent more complete utilisation played a part in this increase.

Similarly, when the 130-acre grazing-trial area was subdivided into 10-acre paddocks, the carrying capacity on the *unimproved* pasture in Paddock 1 in the first year rose from approximately 2 ewe-equivalents per acre to 3.2. This rise in carrying capacity cannot be attributed to any manurial effect or to oversowing, as this paddock is a control area. The increase undoubtedly came from the subdivision into small areas which could be efficiently and fully utilised.

Taking this subdivision effect to the extreme, several small $\frac{1}{20}$-acre paddocks on an easy slope were fenced for experimental purposes. The annual carrying capacity of each of these paddocks has averaged 7 sheep per acre—even on the control plots this figure was achieved in the first year following subdivision.

Research work should be carried out to determine accurately the effect of subdivision on carrying capacity, and also to determine the most economic paddock size. The observations recorded here merely indicate that subdivision may be more important for production than superphosphate without oversowing.

Stock Management

The grazing treatments were started in August, 1948 using an even line of two-tooth ewes averaging 105 lb., and the treatments were adhered to at all times except when it was necessary to graze the pastures closely prior to oversowing.

The sheep were weighed at monthly intervals except at lambing when the interval was increased to approximately two months. Lambs were weighed also until they were sent away (usually at weaning time in early January).

As the pastures improved, it was necessary to bring in additional ewes. Also in growthy seasons extra ewes and cattle were carried to maintain the pastures in the condition prescribed for the grazing treatments.

A varying number of beef cattle was continuously carried on the area, and these were used purely to graze off roughage, unpalatable grass, and weeds. In this, as on all hill farms, they have performed a valuable function. Their presence, however, has brought in an added source of error in that no weighing facilities were available and no measure of thrift could be applied.

On the rotationally grazed area, the sheep were shifted every three and a half days, i.e., on Monday morning and Thursday afternoon, giving ten and a half days spell between grazings for each paddock in the group of four.

TABLE 9. CARRYING CAPACITY OF GRAZING-TRIAL AREA

Paddock No.	Area (acres)	Ewe Days			Ewes Per Acre			*Total Ewe-equivalent Days			*Total Ewe-equivalents Per Acre		
		1948-49	1949-50	1950-51	1948-49	1949-50	1950-51	1948-49	1949-50	1950-51	1948-49	1949-50	1950-51
1	10.0	9936	9704	10571	2.7	2.6	2.9	11606	11815	10571	3.2	3.2	2.9
2	10.0	9925	10343	14564	2.7	2.8	4.0	12085	14895	16244	3.3	4.1	4.5
3	10.0	5680	9768	11259	1.5	2.7	3.1	11130	13224	17814	3.0	3.6	4.9
4	10.0	8069	8510	15174	2.2	2.3	4.2	11204	12178	16764	3.1	3.3	4.6
5	3.6	3333	3590	3334	2.5	2.7	2.5	4228	5385	3334	3.2	4.1	2.5
6	9.4	7824	7666	15196	2.3	2.2	4.4	9181	13796	15876	2.7	4.0	4.6
7	6.6	2084	6652	7403	0.9	2.7	3.1	2634	8992	7403	1.1	3.7	3.1
8	10.6	9681	8907	11683	2.6	2.4	3.0	12493	13087	12743	3.4	3.6	3.3
9	10.0	10126	6917	13720	2.8	1.9	3.8	11896	10004	14660	3.3	2.7	4.1
10	10.0	7882	6347	8546	2.1	1.7	2.3	10407	9945	8971	2.8	2.7	2.5
11	10.0	4380	8059	12349	1.2	2.2	3.4	8275	13180	14202	2.3	3.6	3.9
12	10.0	7845	9160	13472	2.1	2.5	3.7	9257	11736	14807	2.5	3.2	4.1
13	10.0	8528	9374	13550	2.3	2.6	3.7	9838	11243	13970	2.7	3.1	3.8
14	10.0	8716	7209	11813	2.4	2.0	3.2	12941	11558	12613	3.6	3.2	3.5
Average	130.2	103949	112206	162634	2.2	2.4	3.4	137175	161038	181277	2.9	3.4	3.8
No. 1 Rot.	40	35700	32000	55773	2.5	2.2	3.8	45774	49065	60048	3.1	3.4	4.1
No. 2 Rot.	40	29469	33802	51184	2.0	2.3	3.5	40311	47717	55592	2.8	3.3	3.8

*Includes cattle; 1 cattle beast equivalent to 5 ewes

TABLE 10. CORRELATION BETWEEN CARRYING CAPACITY AND AVERAGE EWE WEIGHT

Paddock No.	1948 - 1949			1949 - 1950			1950 - 1951		
	Ewes/Acre	‡ Ewe-equivalents	Av. Ewe Weight	Ewes/Acre	‡ Ewe-equivalents	Av. Ewe Weight	Ewes/Acre	‡ Ewe-equivalents	Av. Ewe Weight
1	2.7	3.2	130	2.6	3.2	131	2.9	2.9	133
2	2.7	3.3	131	2.8	4.1	138	4.0	4.5	144
3	1.5	3.0	Spelled for part of year	2.7	3.6	132	3.1	4.9	139
4, 6, 8, 9	2.5	3.1	116	2.2	3.4	120	3.8	4.1	131
5	2.5	3.2	121	2.7	4.1	129	2.5	2.5	132
7	0.9	1.1	Spelled for part of year	2.7	3.7	111	3.1	3.1	119
10	2.1	2.8	116	1.7	2.7	121	2.3	2.5	120
11, 12, 13, 14	2.0	2.3	117	2.3	3.6	118	3.5	3.8	127
Flock Av.	2.2	2.9	119	2.4	3.4	124	3.4	3.8	130
*Seed and Manure	2.2	3.0	120	2.4	3.6	127	3.2	3.8	132
†No Seed and Manure	1.8	2.2	130	2.7	3.5	121	3.0	3.0	121

* Average of Paddocks 2, 3, 4, 6, 8, 9, 5, 10, 11, 12, 13, 14.
† Average of Paddocks 1 and 7.
‡ Includes cattle: 1 cattle beast equivalent to 5 ewes.

Paddocks 3 and 7 were spelled for two periods of 6 months during the late spring, summer, and early autumn of 1948–49 and 1950–51.

Carrying Capacity on 130 acres

August	1947	under	farmer's	management	195	ewes +	cattle (approx.)
„	1948	under	experimental	management	209	ewes +	cattle
„	1949	„	„	„	263	„	„
„	1950	„	„	„	266	„	„
„	1951	„	„	„	458	„	„

The above flock numbers give an indication of the increase in carrying capacity over the three years since the trials commenced in August 1948. In August 1950, stock numbers could have been considerably increased but ewes could not be purchased to build up the flock to the required level. The surplus pasture-growth was consumed by cattle to a larger extent than before or since that date.

In 1951, a new flock was brought in consisting of 404 2-tooth ewes plus a further 54 4-tooth ewes to makes up the required numbers. The rate of stocking was determined by the feed available in the July–August period when growth is at a minimum. Surplus spring and autumn growth was consumed by cattle.

The relative carrying capacity of the various paddocks in ewe days grazed and in ewe-equivalents is shown in Table 9 for the years 1948–51.

Tables 9 and 10 show the comparative carrying capacities and average ewe weights for the treated and untreated pastures. The lightly stocked Paddock 10 lowers the average for the treated pastures.

Sheep Weights under Different Treatments

The mean weight of ewes month by month in each flock is shown in Fig. 9. The main points of interest are as follows.

The approximate average 2-tooth weight in August 1948 was 105 lb.

In Paddock 1, as the result of an agreement with the owner to run only dry ewes on untreated closely grazed pasture, large live-weight increases were recorded for the first year of the trial. The dry ewes developed into large-boned animals, the top ewe reaching a maximum weight of 185 lb. In the following year, 1949, although no culling was done, the lambing percentage was 107. All the ewes lambed satisfactorily despite the fact that live weight at tupping indicated that all were, according to accepted ideas, carrying too much condition. This flock continued for 2 years to maintain a higher general weight level than all other flocks except that on Paddock 2. This effect gradually disappeared as the pastures improved in the oversown and topdressed areas. The relatively good results on Paddock 1 have largely been due to full utilization of pasture at all times of the year.

Paddock 2: this close and continuous grazing treatment produced the highest average body weight throughout the trial. The paddock was oversown and topdressed and permanently set-stocked. In order to

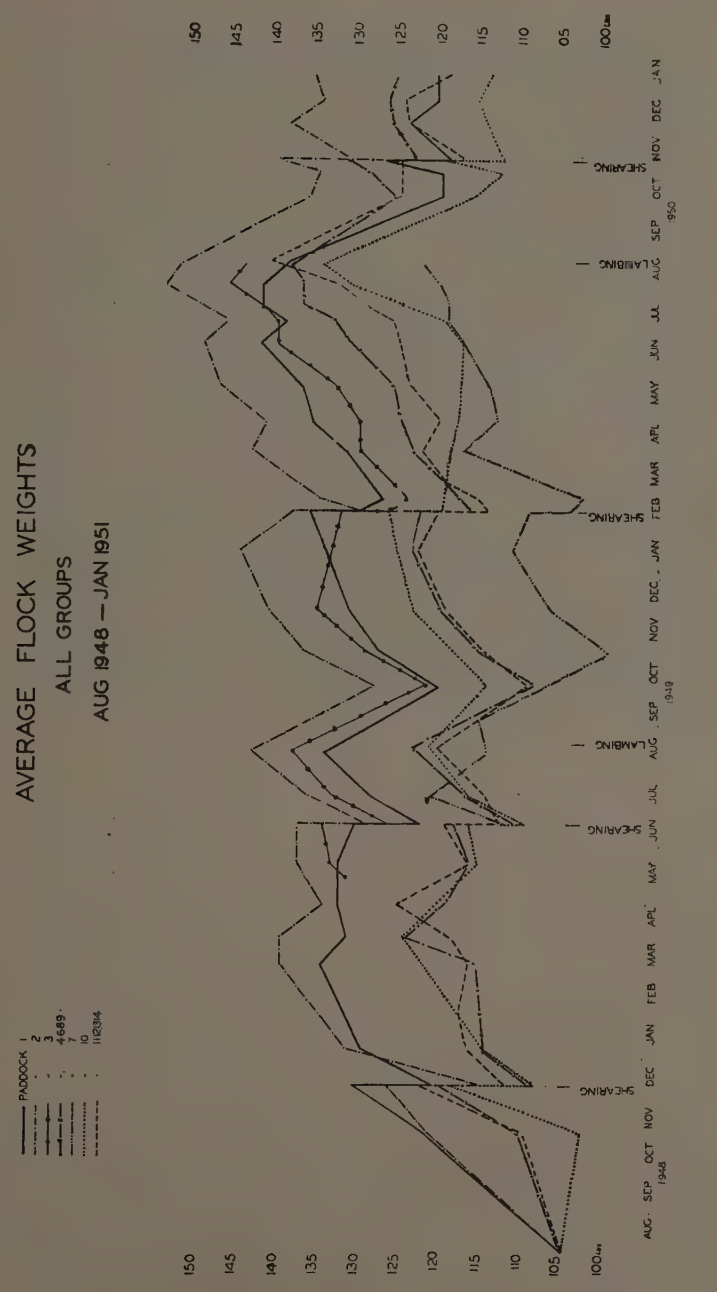

Fig. 9.—Average flock weights for all groups August 1948–51.

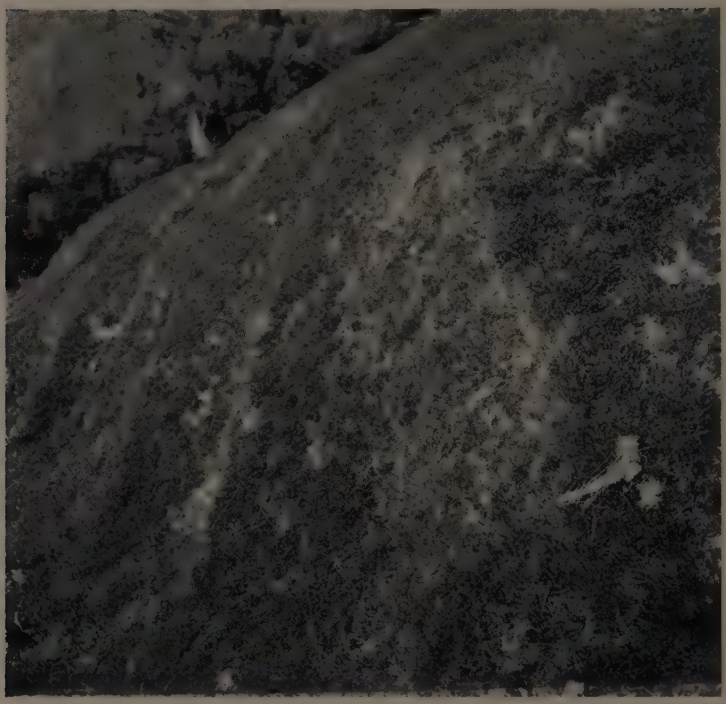

Fig. 10.—Steep hillside showing complete utilisation of pasture on "step" and "riser" areas between slips. Dark strips are stock tracks where higher fertility favours ryegrass and clovers.

keep the sward closely-grazed, additional sheep and cattle were brought in during periods of excess growth. On the closely grazed pastures the herbage is very palatable and nutritious, and contains, a high percentage of protein (Figs. 10 and 11). It is apparent that on hill pastures the poorer species such as browntop, danthonia, and sweet vernal are most unpalatable and lose nutritive value when above 1 to 2 in. in height.

The flock on this area reached 155 lb. average live weight in 1950. Normally a good lambing percentage would not be expected from ewes in such condition but, as in Paddock 1, the lambing percentage was well above the district average (see Table 11).

The management laid down for Paddock 3 allowed for a long spell every second year. Accordingly, no stock was grazed until early May 1949, when ewes of the same age as the ewes in the other flocks were put on the area. Between the spells the management was similar to that of Paddock 2, i.e., close set-stocking, but the ewes were not as thrifty as those in Paddock 2 because of the slow recovery of the pasture following spelling at a stage in treatment when little benefit had been felt from oversowing. Although Paddocks 2 and 3 are both ten acres in area, the latter has more slips and is somewhat steeper than Paddock 2. The

Fig. 11.—Untreated pastures are difficult to control: rank, unpalatable grass can only be removed by grazing heavily with cattle.

newly treated raw slip has reduced the amount of grass available for grazing and adversely affected sheep weights. The area was again spelled in 1950.

The average weight of ewes in Paddock 4, 6, 8, and 9 under rotational grazing was consistently lower than in Paddocks 2 and 3 under close continuous grazing.

This can be attributed to the fact that too few stock were being grazed on the four 10-acre paddocks to control growth effectively. Great difficulty was experienced in cleaning off coarse growth at each grazing, with the result that the flock was lightly grazing coarse rank pasture rather than close-grazed pasture.

Patch grazing became apparent, with areas of short pasture scattered among rank and unpalatable patches. This patchiness increased throughout the trial. In order to overcome this difficulty and to keep the rotationally grazed area more comparable with the closely grazed pasture (i.e., fully utilised) it was necessary to increase stock numbers and to change from regular 3½ day shifts to a rotation based on full utilisation of each paddock before shifting on to the next. When this was done animal thrift improved.

Paddock 7 received no seed or fertiliser but was long-spelled over the same periods as Paddock 3. Management for both paddocks was

TABLE 11. LAMBING PERCENTAGES ESTIMATED ON NUMBERS OF EWES PUT TO RAM AND OF LAMBS DOCKED

Paddock No.	1948 2'ths			1949 4'ths			1950 6'ths			1951 2'ths		
	Ewes	Lambs	%	Ewes	Lambs	%	Ewes	Lambs	%	Ewes	Lambs	%
	11*											
1	9	8	89	26	28	107	25	27	108	30	22	73
2	16	17	106	28	29	104	27	28	104	37	34	92
3	16	12	75	28	28	100	—	—	—	38	42	111
4, 6, 8, 9	64	53	83	71	80	113	90	99	110	158	134	85
7	10	7	70	14	19	135	—	—	—	20	19	95
10	15	14	93	14	17	121	22	35	159	26	25	96
11, 12, 13, 14	62	52	84	73	76	104	93	106	114	140	135	96
5	6	5	83	9	12	133	9	14	156	9	10	111
Total flock	209	—	—	263	—	—	266	—	—	458	—	—
Total lambs	—	168	—	—	289	—	—	309	—	—	421	—
Av. Lambing %	—	—	80	—	—	110	—	—	116	—	—	92

*Dry ewes from other groups

identical between spells, but the carrying capacity of the untreated area was lower than that of the topdressed and oversown paddock, and the average ewe weight was the lowest for all treatments. The ewes from this paddock were very poor; even six months after they were removed from the area they could be readily identified.

Spelling or light grazing of treated pastures is clearly a practice to be avoided where breeding ewes are to be grazed. Great difficulty was experienced in inducing cattle to clean up the roughage following spelling.

Paddock 10—light grazing: the ewes were of lower average weight than those under other treatments, except Paddock 7. Again, this can be attributed to the patch grazing described previously.

Rotationally grazed paddocks 11, 12, 13, 14: This series of rotationally grazed paddocks is different from the series 4, 6, 8, 9 in that Paddock 11 was spelled for the lean winter period whereas Paddock 14 was regularly spelled from December to March to cater for summer droughts and to allow the oversown clovers to reseed to some extent. In the main this system has proved satisfactory. The average ewe weight has been fairly low but generally better than in Paddocks 7 or 10. The effect of saving pasture for winter feed has been to give a marked increase in ewe weight in the second year when the clovers and topdressing had taken effect.

Difficulties in management arose similar to those encountered in the other rotationally grazed areas where there was insufficient subdivision into sunny and shady faces. Most of the grazing took place on the sunny faces which, especially in winter, became overgrazed, while the shady faces became rank and unpalatable.

Tupping and Lambing

During tupping in 1949 it was not possible to retain the individual groups because of the limited number of rams available. The flock was therefore drafted into two wool-types and grazed in different paddocks. During the first three weeks of tupping, the flocks were used to graze down the surplus grass on the area, prior to oversowing and topdressing. They were forced to graze hard on each paddock before being shifted to a fresh paddock and the ewe weights were consequently down. Tupping began in the last week of March with Romney rams, which remained with the flocks for one month. Southdown rams were then substituted for the next three weeks at the end of which time they also were removed from the area.

In 1950, the rams were again put out on 20 March. The ewe flocks were maintained, however, in their seperate groups, as sufficient rams were available. The rams were shifted to a new flock each fortnight to overcome a possible lack of fertilisation due to sterile rams. In the larger groups it was necessary to put 3 rams where 2 would have been sufficient, to overcome any tendency to fight.

Lambing started on 20 August and continued through September and early October. The long shifts necessary in the rotational grazing groups caused some mis-mothering. In the early stages the whole flock, including newly lambed ewes, were shifted, but as the season of 1949 advanced, and during the 1950 lambing season, it proved more satisfactory to leave new-born lambs behind with their mothers and pick them up on the next rotation. In this way less mis-mothering occurred. The rotational-grazing ewes soon became accustomed to shifts at lambing and there was little mis-mothering.

TABLE 12. AVERAGE DAILY INCREASE IN LAMB WEIGHTS (LB.) FOR THE LAST MONTH (APPROX.) PRIOR TO WEANING AND THE AVERAGE LAMB WEIGHTS (LB.) AT WEANING FOR EACH GRAZING TREATMENT

Paddock No.	1948			1949			1950			1951		
	6/12/48	4/1/49	Daily Increase	1/12/49	28/12/49	Daily Increase	4/12/50	20/12/50	Daily Increase	22/11/51	6/12/51	Daily Increase
1	47	57	0.34	50	59	0.32	52	52	Nil	40	44	0.26
2	58	61	0.01	56	64	0.28	57	58	0.06	45	52	0.46
3	—	—	—	50	61	0.39	—	—	—	45	50	0.33
4, 6, 8, 9	59	67	0.27	52	58	0.21	46	50	0.25	37	41	0.26
5	52	62	0.34	52	64	0.42	48	51	0.18	46	53	0.46
7	—	—	—	38	44	0.21	—	—	—	41	42	0.06
10	62	69	0.24	57	65	0.28	52	57	0.31	40	45	0.33
11, 12, 13, 14	57	63	0.20	51	54	0.10	47	52	0.31	39	44	0.33

Table 11 shows a marked increase in lambing percentages which were well above the district average of 100% for 1950; this is believed to be due in part to better shepherding, but predominantly to better nutrition. It must be borne in mind, however, that in 1948 and 1951 the entire flock consisted of two-tooths.

Daily Gain in Lamb Weight

The average lamb weights at weaning and the daily increase in weight over the last month prior to weaning are shown in Table 12. Little significance can be attached to the figures, because:

Although the rams were put out in each group at the same time, instances were recorded of infertile rams. In consequence the groups which were not put in lamb during the first heat commenced lambing three weeks later. This of course is a problem associated only with these small experimental flocks and, in spite of fortnightly changes in rams from group to group, there were wide variations in lambing date. Late lambs on hill country usually do poorly. The ewe and the feed generally dry up together, forcing the late lamb on to a poor grass diet at an early age. It is proposed to select lambs of similar age from all flocks for future measurement of lamb thrift rather than to deal with the whole flock, as in the past.

Fleece Weights

There was little variation from the mean of 2.2 lb. of wool per lamb between the different groups in any of the three lambing seasons.

It is the practice in this district to shear during October and November but on the grazing-trial area the flock was winter-shorn.

Every fleece from the experimental flocks was weighed, but the weights given in Table 13 do not include pieces. No skirting was done and the "bellies" were weighed with the fleece.

The average fleece weight for 2-tooth ewes was 10.8 for the 1948 season. This represents 13 months' growth of wool. In the second period of 6 months an average of 7.25 lb. of wool was clipped; the third shearing followed a period of 8 months and produced 6.25 lb. of wool from 4-tooth ewes, making a total of 13.5 lb. for 14 months.

It is difficult, from the figures so far recorded, to compare total annual production figures with known standards for ewes of various ages. However, the total quantities produced over a period of 2 years 7 months show that the flocks on the area averaged 10.2 lb. of wool per annum.

Paddocks 2 and 5, under hard continuous grazing, produced more wool than the average for all the experimental flocks. The average wool weights from the rotational grazing groups were just below the general average.

Of the remaining paddocks only No. 10 produced a lower mean fleece weight than the control paddock. What effect long spelling, such as in Paddocks 3 and 7, has on wool production cannot be determined from the figures available. Lenient set-stocking resulted in a lower average fleece weight.

TABLE 13. FLEECE WEIGHTS, TE AWA GRAZING TRIALS 1948 TO 1951

	Shearing Date	Paddock 1	Paddock 2	Paddock 3	No. 1 Rot.	No. 2 Rot.	Paddock 5	Paddock 10	Paddock 7	Average of Flock
2-tooths	6/12/48	11.0	11.8	—	10.8	10.6	11.1	10.2	—	10.8
4-tooths	22/6/49	7.8	8.1	8.0	7.3	6.6	7.6	6.8	—	7.25
4-tooths	17/2/50	6.3	7.2	6.3	6.3	6.1	6.7	6.4	4.7	6.25
6-tooths	24/11/50	7.3	8.9	—	8.4	7.9	8.1	7.0	—	8.0
2-tooths	1/7/51	8.3	8.4	—	8.6	8.4	8.5	8.6	—	8.5
	Total	40.7	44.4	14.3	41.4	39.6	42.0	39.0	4.7	40.8

Losses

From the commencement of the trial in August 1948, stock losses averaged 4% per annum. Deaths were largely due to lambing troubles, 50% of the total deaths being due to this cause; bearing trouble accounted for 10%; a further 10% died through falling in underrunners; and the remaining 30% died of various causes such as dip poisoning, blood poisoning, and sleepy sickness. There was no apparent correlation between stock losses and treatments.

Footrot

In the early stages of the trials, considerable trouble was experienced with footrot. The rotationally grazed areas 4, 6, 8 and 9 were particularly badly infected, although the trouble was evident in all other groups to a lesser extent. A new bulldozed track passed through Paddocks 8 and 9 and the sheep used this track as a camping ground. It is probable that the bare roadway acted as a carrier for the disease.

Repeated treatment in a bluestone bath and constant attention to trimming affected feet soon reduced the trouble. The rotationally grazed groups did not benefit from the spelling because the period between grazings was too short to eliminate the infection. Since the rotational grazing areas have been further subdivided, the spell between grazings has lengthened so that there is little carry-over of the disease from one grazing to the next in the same paddock.

It was most noticeable throughout the three-year period that those animals affected with footrot were underweight and unthrifty generally.

SUMMARY OF MANAGEMENT TRIAL RESULTS

The first two years of the grazing trials were of an exploratory nature. Difficulties were met, some of which have been overcome. Valuable information has been gained to facilitate trials in the future. The main points arising from the investigation may be summarised as follows.

Stock numbers must be increased in accordance with the improvements effected by oversowing, topdressing, and subdivision.

Close grazing has given the best results; it ensures palatability, full utilisation, and improved animal thrift.

Rotationally grazed areas must be fully grazed before the flock is shifted, otherwise the areas become patch grazed. This effectively reduces the area of palatable pasture to the stage where animal thrift is detrimentally affected.

Full utilisation of both the set-stocked and rotationally grazed areas provides for the animals a short, palatable, high-protein feed on which they thrive.

The chief object on hill country is to avoid rank unpalatable herbage. The pasture species available are palatable at $\frac{1}{2}$ to 1 in. but beyond this height become hard and unpalatable.

Light grazing and long spelling result in poor thrift. The carrying capacity of a lightly grazed area is essentially that of the close-grazed patches; the remainder yields a maintenance diet of roughage.

Acknowledgements

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Appendix

Introduced Plants

In September 1948 a large number of grass and clover species were planted as rooted plants at Te Awa to determine whether any of the species introduced from overseas would prove useful on the hill country in this district. Prior to planting on the hills, seed of these species had been sown in boxes, and seedlings were grown to the stage where it was considered they would be sufficiently hardy to survive. Each individual plant was dibbled into the existing turf while soil moisture conditions were favourable for establishment.

A total of 61 rows were planted containing approximately 30 plants per row. The following list shows the species tested:

Agropyron cristatum	Crested wheatgrass
Agropyron elongatum	
Agropyron scabrum	Blue wheatgrass
Agrostis alba	Redtop
Briza brizoides	
Bromus carinatus	
Bromus catharticus	Prairie grass
Bromus coloratus	
Chloris canteria	
Chloris gayana	Rhodes grass
Danthonia pilosa	Danthonia
Danthonia cirrhata	
Ehrharta calycina	
Eragrostis chloromelas	
Eragrostis curvula	

Festuca arundinacea	Tall fescue
Festuca arundinacea elatior	"Alta" fescue
Hordeum ischnatherum sp.	
Lolium spp.	Ryegrass
Lotus americanus	
Lotus corniculatus	Birdsfoot trefoil
Lotus humistratus	Birdsfoot trefoil
Lotus scoparius	Birdsfoot trefoil
Lotus uliginosus	Greater birdsfoot trefoil
Lotus uliginosus glabriusculus	Greater birdsfoot trefoil
Lotus uliginosus villosus	Greater birdsfoot trefoil
Phalaris tuberosa	Toowoomba grass
Poa lanigera	
Poa pratensis	Kentucky bluegrass
Polypogon monspeliensis	Beard grass
Rottboellia selloana	
Stipa bavioensis	Speargrass
Stipa megapotamia	Speargrass
Stipa neesiana	Speargrass
Trifolium fragiferum	Palestine strawberry clover
Trifolium glomeratum	Clustered clover
Trifolium hybridum	Alsyke clover
Trifolium striatum	Striated clover
Trifolium subterraneum (vars. "Baccus Marsh", "Burnerang", "Nangeela")	Subterranean clover

Under normal hill-pasture competition most of the plants failed to survive the 3 year period. Some still persist (1951), but in few instances have these species proved worthy of further investigation and trial. Similar trials carried out in other areas, viz, Palmerston North, Sherenden, Mangapehi, Hatuma, and Mt. Erin Station in Hawke's Bay, have shown similar results to those at Te Awa.

SCREENING TESTS WITH FUNGICIDES FOR CONTROL OF BROAD-BEAN RUST

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Summary

Thirty-three fungicides were tested in the glasshouse for control of *Uromyces fabae* (Pers.) de Bary.

Most effective compounds were lime sulphur, Colsul 40, Cosan, Dithane Z78, Fermspray, Manzate, Thirospray, Fuclasin Ultra, Flit 406, Phygon XL, and Spergon w.p.

Other test materials were not as effective as the above.

Introduction

Broad-bean rust, first recorded in New Zealand by Kirk (1905), is a serious disease of broad beans. Many screening tests with fungicides using this fungus as test organism, were carried out prior to investigating the field performance of the most effective compounds. Results are reported herein.

Materials Used

Copper compounds: Bordeaux mixture; Cop-ox (50% copper oxychloride) wettable powder; Perenox (50% cuprous oxide) wettable powder; copper zeolite (50% copper) wettable powder; Blue Ammon (4.5% copper ammonium sulphate) liquid; Ialine colloidal copper (15% copper oxychloride) emulsion; and Fungex (8.5% copper ammonium carbonate) liquid.

Sulphur compounds: Lime sulphur (15% polysulphide) liquid; Colsul 40 (40% colloidal sulphur) paste; Wetomic sulphur (80% sulphur) wettable powder; and Cosan (75% sulphur) wettable powder.

Dithiocarbamates: Dithane Z78 (65% zineb) wettable powder; Dithane D14 (x/y/z = x lb. of 25% nabam/y lb. of zinc sulphate/z lb. of hydrated lime) wettable powder; Fermspray (70% ferbam) wettable powder; Manzate (70% manganese ethylene bisdithiocarbamate) wettable powder; Thirospray (50% thiram) wettable powder; Vancide (30% nabam plus 2 mercapto benzothiazole) wettable powder; cupram (technical cupric dimethyl dithiocarbamate) powder; Zirospray (70% ziram) wettable powder; and Fuclasin Ultra (70% ziram) wettable powder.

Miscellaneous compounds: Flit 406 (50% captan) wettable powder; Phygon XL (50% dichlone) wettable powder; Spergon w.p.

(48% chloranil) wettable powder; Shirlan A.G. (25% salicylanilide) paste; Crag 341C (34% glyodin) liquid; Crag 5379 (75% 1, 2, 3 trithio-5, 8 diazocyclonane-4, 9 dithione) liquid; Crag 5400 (75% alpha, alpha, trithio bis (n-dimethyl thiophormamide) liquid; Crag 658 (15% cuprous oxide plus 10% zinc oxide plus 6% chromium oxide) liquid; Crag 1182 (3.8% 4 chloro-3, 5 dimethylphenoxy ethanol) wettable powder; Murfixtan (0.8% phenyl mercury salt of naphthyl methane sulphonic acid) liquid; Ascospray (2.5% phenyl mercury chloride) wettable powder; Midol (0.3% phenyl mercury chloride) emulsion; and Nirit (15% dinitrobenzene) wettable powder.

EXPERIMENTAL METHODS

Broad-bean seed of the variety Yates Early Longpod was sown in 4-in. pots, one seed per pot. Two weeks after emergence, four plants for each treatment were sprayed with 50 ml. of the fungicidal suspensions, a quantity found to be sufficient to allow thorough wetting of test plants. Check plants were sprayed with 50 ml. of water.

Twenty-four hours later, plants were inoculated with a rust-spore suspension containing 25,000 to 30,000 spores per ml. After inoculation, plants were placed in a humidity cabinet (88.5% $\pm$ 3.5% relative humidity at 65.7°F $\pm$ 1.5°F) for 24 to 36 hours. Plants were then moved to a glasshouse held at 75.7°F. $\pm$ 2.6°F. Under these conditions high infection was obtained. Lesion counts were made on four lower leaves of each plant 10 to 14 days after inoculation.

The aim of these screening tests was to select materials giving as complete inhibition of infection as possible. Any material used in the first trial (Table 1) that was not significantly different in efficacy from the most effective treatments (viz. those completely inhibiting rust development) was retested (Table 2). In the final selection, effective concentrations were tested twice more, figures listed being the means of two tests (Table 2).

RESULTS

Copper compounds allowed a relatively large number of rust lesions to develop. Of the sulphur compounds, lime sulphur, colloidal sulphur, and the finer wettable sulphur (Cosan), were more effective than the coarser Wetomic Sulphur. Some carbamates were more effective than others in inhibiting rust infection; Dithane Z78, Manzate, and Fuclasin Ultra, being more effective than Dithane D14, Vancide, Zirospray, and Cupram. Fermspray and Thirospray allowed a greater number of lesions to develop than Dithane Z78, Manzate, and Fuclasin Ultra, but differences were not significant. Some compounds, e.g. Manzate, were less effective at higher concentrations than at the lower, which confirms observations made by Dye (1953). Of compounds other than those mentioned, Flit 406, Phygon XL, and Spergon w.p., were the most effective. The following materials did not give adequate control of the rust: Shirlan A.G., Crag 341C, Crag 5379, Crag 5400, Crag 658, Crag 1182, Murfixtan, Ascospray, Midol, and Nirit.

TABLE 1. TRIAL 1. EFFECT OF VARIOUS FUNGICIDES APPLIED AT

Copper Compounds				Sulphur Compounds			
Material	Amounts in 100 gal. water	Mean No. of lesions per leaf	Transformed log (X + 1)	Material	Amounts in 100 gal. water	Mean No. of lesions per leaf	Transformed log (X + 1)
Check	—	638.2	2.81	Check	—	931.3	2.97
Bordeaux mixture	10 lb.: 8 lb.	32.0	1.53	Lime sulphur	2 gal.	0.0	0.00
"	6 lb.: 8 lb.	35.2	1.56	" "	1 gal.	0.0	0.00
				" "	0.75 gal.	0.0	0.00
Cop-ox	10 lb.	16.0	1.26	" "	0.5 gal.	5.0	0.78
"	5 lb.	30.2	1.53	" "	0.25 gal.	14.5	1.42
"	2.5 lb.	85.5	1.93	Lime sulphur:			
				Colsul 40	1 gal.: 2 lb.	0.0	0.00
Perenox	10 lb.	13.7	1.18	" " "	1 gal.: 1 lb.	0.0	0.00
"	5 lb.	40.2	1.62	" " "	0.75 gal.: 2lb.	0.0	0.00
"	2.5 lb.	95.2	1.99	" " "	0.75 gal.: 1 lb.	0.0	0.00
				" " "	0.5 gal.: 2 lb.	0.0	0.00
Copper zeolite	10 lb.	80.5	1.91	" " "	0.5 gal.: 1 lb.	0.0	0.00
"	5 lb.	152.0	2.19	" " "	0.25 gal.: 2 lb.	5.0	0.76
"	2.5 lb.	457.0	2.65	" " "	0.25 gal.: 1 lb.	6.0	0.85
Blue Ammon*	3 gal.	33.2	1.54	Colsul 40	16 lb.	0.0	0.00
" " *	1.5 gal.	40.5	1.61	"	12 lb.	0.0	0.00
" " *	0.75 gal.	74.7	1.88	"	8 lb.	2.3	0.50
				"	4 lb.	5.0	0.78
Ialine Col. copper	2 gal.	48.7	1.70	"	2 lb.	12.0	1.11
" " "	1 gal.	62.3	1.81	"	1 lb.	38.0	1.59
" " "	0.5 gal.	43.5	1.65	Wetomic sulphur	8 lb.	10.3	1.04
Fungex	0.5 gal.	30.6	1.51	" "	4 lb.	82.0	1.92
"	0.25 gal.	35.0	1.57	" "	2 lb.	147.0	2.17
				Cosan	8 lb.	0.0	0.00
				"	6 lb.	0.0	0.00
				"	4 lb.	4.3	0.70
				"	2 lb.	18.3	1.28
Difference required for significance at :	5%		0.51				0.51
	1%		0.67				0.67

*Phytocidal effects. Treatments causing necrotic spotting on leaves the severity of which

SEVERAL CONCENTRATIONS ON DEVELOPMENT OF BROAD-BEAN RUST

Dithiocarbamates				Miscellaneous Compounds			
Material	Amounts in 100 gal. water	Mean No. of lesions per leaf	Transformed log (X + 1)	Material	Amounts in 100 gal. water	Mean No. of lesions per leaf	Transformed log (X + 1)
Check	—	856.8	2.93	Check	—	933.5	2.97
Dithane Z78	8 lb.	0.0	0.00	Flit 406	2 lb.	0.0	0.00
,,	6 lb.	1.6	0.42	,, ,,	1 lb.	22.8	1.36
,,	4 lb.	12.6	1.15	,, ,,	0.5 lb.	117.0	2.07
,,	2 lb.	20.6	1.34	Phygon XL	1 lb.	0.0	0.00
Dithane D14	6 lb.: 3 lb.: 1.5 lb.	6.6	0.90	,, ,,	0.5 lb.	0.0	0.00
,,	4 lb.: 2 lb.: 1 lb.	25.0	1.42	,, ,,	0.25 lb.	0.0	0.00
,,	2 lb.: 1 lb.: 0.5 lb.	29.0	1.48	Spergon w.p.	2 lb.	0.0	0.00
Fermspray	6 lb.	3.2	0.60	,, ,,	1 lb.	0.0	0.00
,,	4 lb.	7.8	0.90	,, ,,	0.5 lb.	0.1	0.04
,,	2 lb.	19.0	1.30	,, ,,	0.25 lb.	4.2	0.70
,,	1 lb.	33.6	1.53	Shirlan A.G.	6 lb.	118.3	2.08
Manzate	4 lb.	8.5	0.95	,, ,,	3 lb.	131.3	2.12
,,	2 lb.	5.5	0.78	Crag 341 C	2 lb.	53.0	1.73
,,	1 lb.	1.0	0.30	,, ,,	1 lb.	63.6	1.81
,,	0.5 lb.	0.0	0.00	Crag 5379	2 lb.	30.6	1.49
Thirospray	8 lb.	8.7	0.95	,, ,,	1 lb.	39.6	1.60
,,	4 lb.	3.4	0.60	Crag 5400	2 lb.	16.6	1.23
,,	2 lb.	7.3	0.90	,, ,,	1 lb.	19.0	1.30
,,	1 lb.	18.6	1.28	Crag 658	2 lb.	32.3	1.52
Vancide*	8 lb.	38.6	1.59	,, ,,	1 lb.	36.3	1.57
,,	4 lb.	12.2	1.11	Crag 1182	2 lb.	40.6	1.61
,,	2 lb.	30.5	1.49	,, ,,	1 lb.	49.0	1.70
,,	1 lb.	45.5	1.66	Murfixtan	6 pts.	76.7	1.89
Cupram	4 lb.	30.6	1.49	,,	3 pts.	367.2	2.57
,,	2 lb.	33.3	1.53	Ascospray*	2 lb.	14.0	1.18
,,	1 lb.	41.3	1.62	,, *	1 lb.	212.5	2.33
Zirospray	6 lb.	6.8	0.85	Midol	1 gal.	422.7	2.63
,,	4 lb.	33.2	1.53	,,	0.5 gal.	744.7	2.87
,,	2 lb.	67.7	1.83	Nirit	2 lb.	174.5	2.24
Fuclasin Ultra	6 lb.	0.5	0.14	,,	1 lb.	145.2	2.16
,, ,,	4 lb.	0.5	0.16				
,, ,,	2 lb.	0.5	0.15				
,, ,,	1 lb.	2.5	0.56				
			0.51				0.51
			0.67				0.67

increased with higher concentrations.

TABLE 2. TRIAL 2. SELECTION OF THE MOST EFFECTIVE TREATMENTS IN PREVENTION OF BROAD-BEAN RUST

Treatments selected from Table 1				Final selection			
Material	Amounts in 100 gal. of water	Mean No. of lesions per leaf	Transformed log (X + 1)	Material	Amounts in 100 gal. of water	Mean No. of lesions per leaf	Transformed log (X + 1)
Check	—	317.3	2.57	Check	—	295.8	2.48
Lime sulphur	0.75 gal.	0.0	0.00	Lime sulphur	0.75 gal.	0.0	0.00
" "	0.5 gal.	6.3	0.86	Lime sulphur : Colsul 40	0.5 gal.: 2 lb.	0.0	0.00
Lime sulphur : Colsul 40	0.5 gal.: 2 lb.	0.0	0.00	Colsul 40	10 lb.	0.0	0.00
" " : " "	0.5 gal.: 1 lb.	2.4	0.55	Cosan	5 lb.	0.0	0.00
Colsul 40	10 lb.	0.0	0.00	Dithane Z78	4 lb.	0.0	0.00
"	8 lb.	1.8	0.46	Fermspray	5 lb.	0.0	0.00
Cosan	5 lb.	0.0	0.00	Manzate	0.5 lb.	0.0	0.00
"	4 lb.	2.0	0.49	Thirospray	4 lb.	0.1	0.03
Dithane Z78	6 lb.	0.0	0.00	Fuclasin Ultra	2 lb.	0.3	0.10
"	4 lb.	0.2	0.06	Flit 406	2 lb.	0.1	0.04
Fermspray	6 lb.	0.0	0.00	Phygon XL	0.25 lb.	0.0	0.00
"	5 lb.	1.0	0.30	Spergon w.p.	0.5 lb.	0.1	0.03
Manzate	1 lb.	0.0	0.00				
"	0.5 lb.	0.0	0.00				
Thirospray	4 lb.	0.0	0.00				
Fuclasin Ultra	2 lb.	0.5	0.16				
"	1 lb.	2.8	0.59				
Flit 406 "	2 lb.	0.5	0.15				
Phygon XL	0.5 lb.	0.0	0.00				
"	0.25 lb.	0.0	0.00				
Spergon w.p.	1 lb.	0.0	0.00				
"	0.5 lb.	0.2	0.07				
Difference required for significance at:	5%		0.35				0.35
	1%		0.46				0.46

CONCLUSIONS

In Table 2 it is shown that under these test conditions satisfactory control was secured with lime sulphur at 0.75 gal. in 100 gal. water, lime sulphur at 0.5 gal. combined with Colsul 40 at 2 lb., Colsul 40 at 10 lb., Cosan at 5 lb., Dithane Z78 at 4 lb., Fermspray at 5 lb., Manzate at 0.5 lb., Thirospray at 4lb., Fuclasin Ultra at 2 lb., Flit 406 at 2 lb., Phygon XL at 0.25 lb. and Spergon w.p. at 0.5 lb. in 100 gal. water. The other compounds, at concentrations tested, did not provide adequate control on test plants.

ACKNOWLEDGEMENT

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FRENCH-BEAN RUST (*Uromyces appendiculatus*) IN NEW ZEALAND

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Summary

French-bean rust (*Uromyces appendiculatus*) was first recorded in New Zealand in April 1951.

Symptoms, factors favouring infection and spread, and morphology of the causal organism have been described.

Forty varieties of dwarf and runner beans have been tested for resistance by artificial inoculation.

Preliminary tests have shown that lime sulphur 1-150 plus colloidal sulphur 2 lb. to 100 gal. is effective in controlling bean rust.

INTRODUCTION

French-bean rust caused by *Uromyces appendiculatus* (Pers.) Unger, was first recorded in New Zealand in April 1951 on late crops of dwarf and runner beans (varieties, Sydney Wonder, Kentucky Wonder, and Fardenlosa) grown in the Auckland district. In 1952, the disease first appeared early in March on Fardenlosa and Market Wonder beans in the Mangere area. By the end of March approximately 50% of the late crops at various stages of maturity showed evidence of rust infection on leaves, and during April the disease was widespread in all bean crops in the vicinity of Auckland. Although in most cases infection was slight, affecting only the older leaves, in some crops foliage was severely damaged and yields considerably reduced. Rust infection has not been recorded on bean crops earlier than March. Apart from market and domestic gardens in the Auckland area, and an unconfirmed report from a domestic garden at New Plymouth, the disease has not been observed in New Zealand.

In this paper, symptoms, factors favouring infection, and morphology of the causal organism are described. Varietal resistance is discussed and control measures recommended.

SYMPTOMS

Bean rust attacks leaves, pods (Figs. 1 and 2), and, occasionally, tender parts of stems. It is most abundant on leaves where it first appears as minute, light-coloured, slightly raised spots or pustules (uredosori). These usually develop first on undersides of leaves, but later are abundant on both surfaces. Pustules gradually increase in size and may attain a diameter of 1 to 2 mm. After a few days, the enlarging uredosori rupture the epidermis and expose cinnamon-brown spore masses (uredospores). When heavy infection occurs, a ring of secondary uredosori may develop outside the original pustule. Severely infected leaves become shrivelled and later fall from the plant. Defoliation causes stunting of growth and consequent reduction in yield. As plants mature and leaves commence to die, the spore masses turn dark brown to black, as uredespores are replaced by overwintering spores (teleutospores).

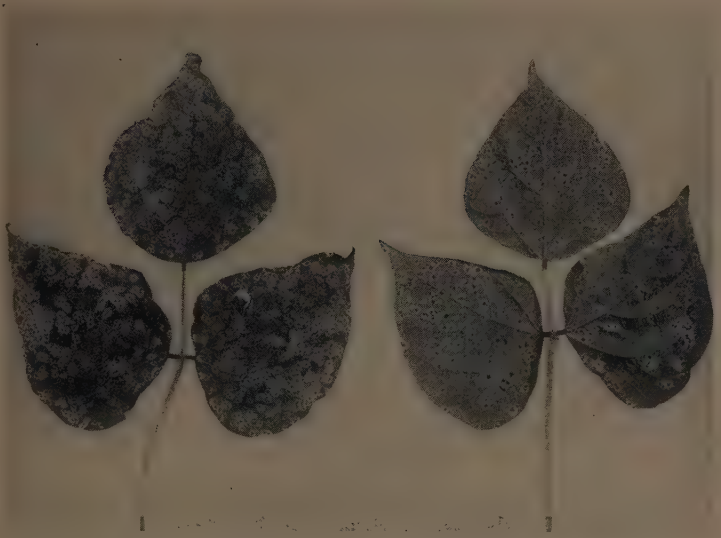

Fig. 1.—Severe infection of bean rust on leaves of runner bean. Left, upper surface: right, under surface.

Photo: S. A. Rumsey

Fig. 2.—Rust pustules (uredosori) on runner bean pods.

Photo: S. A. Rumsey

FACTORS FAVOURING INFECTION AND SPREAD

Bean rust is disseminated mainly by spores, which may be carried by wind over long distances. Uredospores are produced in large numbers on infected plants and are able to germinate as soon as they are mature. Under favourable conditions of temperature and humidity they produce

further generations of spores in 10–15 days. Teleutospores, however, require a dormant period before germination. They retain their viability for more than 6 months and serve to carry over the fungus from year to year on dead leaves and other bean refuse that have not been destroyed or ploughed in. They may also overwinter on stakes used to support an infected crop (Milbrath, 1944). A temperature of 17°C. is optimum for infection and a relative humidity of 95% for 8 to 12 hr. is essential.

Morphology

The following description of the organism has been drawn from a study of infected bean leaves collected at Auckland.

Uromyces appendiculatus (Persoon) Unger. *in Einfluss des Bodens, Vertheilung der Gewachse, nachgewiesen der Vegetation des nordostlichen Tirols.* p. 216, 1836.

Synonyms: Uredo appendiculata Pers. *Synopsis methodica Fungorum.* p. 221, 1801.

Uredo appendiculata var. *phaseoli* Pers. *ibid.* p. 222.

Uromyces phaseoli (Pers.) Wint. *Rabenhorst Kryptogamen-Flora,* I. p. 157, 1884.

Pycniosori epiphyllous, immersed, finally erumpent, obpyriform, honey-coloured, in minute clusters, 160μ diam.

Aecidiosori hypophyllous, crowded, orbicular, 1 to 2 mm. diam., white; peridia cupulate, 540μ diam., with revolute dentate margins. Aecidiospores, polygonal, 20–30 × 14–21μ (average 22 × 18μ); epispore hyaline, finely verrucose, 1 to 2μ thick.

Uredosori amphigenous, on leaves, stems and pods, scattered or in groups, 1 to 2 mm., orbicular, pulvinate, cinnamon-brown, naked, surrounded by ruptured epidermis. Uredospores subglobose or broadly elliptical, 24–30 × 20–24μ (average 26 × 22μ); epispore thin-walled, sparsely aciculate, 1.6μ thick, light brown; with two equatorial germ pores.

Teleutosori amphigenous, on leaves and stems, scattered, orbicular, pulvinate, fuscous to black, naked, to 1 mm. in diameter; teleutospores sub-globose to elliptical, stalked, with hyaline, truncated papilla, 27–35 × 20–27μ (average 29 × 24μ); epispore smooth, dark brown, to 3.5μ thick; pedicel hyaline, persistent, to 20μ long.

Distribution: Europe, North and South America, India, Africa, China, Japan, Philippine Islands, Australia, New Zealand.

Host range in New Zealand: Phaseolus vulgaris L. (dwarf and runner beans).

Aecidiosori, although rare, have been collected in Auckland (Fig. 3). Uredosori and teleutosori are abundant in the autumn on dwarf and runner beans in Auckland. Overseas, the rust has been recorded additionally on *Phaseolus coccineus* (scarlet runner) and *P. lunatus* (lima bean).

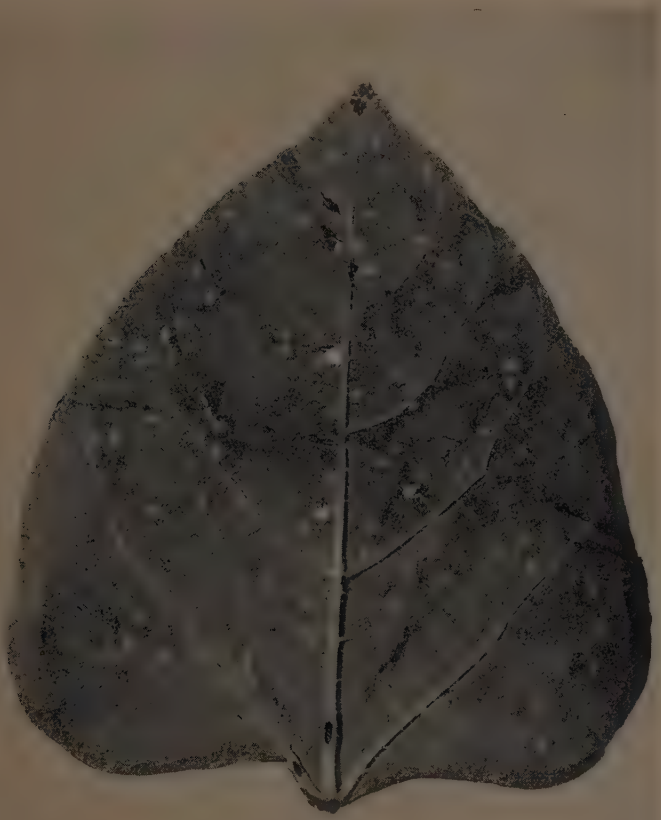

Fig. 3.—Aecidiosori on bean leaf.

Photo: J. W. Endt

RESISTANT VARIETIES

During 1953, 40 varieties of dwarf and runner beans were tested, by artificial inoculation in the glasshouse, for resistance to the strain of *U. appendiculatus* present in New Zealand. Of these, Westralia, a runner variety recently developed in Western Australia (Cass Smith *et al.*, 1951), was highly resistant (Fig. 4), and Fullgreen, a dwarf variety raised in the United States (Andrus and Hoffman, 1950) was resistant. The remainder were either susceptible or highly susceptible. These are as follows:—

Susceptible: (50 to 100 uredosori per leaf, average of 16 leaves) Blanda Stringless, Geneva Market, Scarlet Runner.

Fig. 4.—On left, susceptible variety; on right, resistant following artificial inoculation.

Photo: S. A. Rumsey

Highly Susceptible: (100 or more uredosori per leaf, average of 16 leaves) Alabaster II, Anla Stringless, Asgrow Stringless, Beka, Beurre d' Alger noir nain, Black Prince, Bright's Refugee, Canadian Wonder, Cupetor, Dauphin, Express Yellow Pod, Fardenlosa, Full Measure, Golden Harvest, Granda, Haricots, Hawkesbury Wonder, Henrich Giant, Hundred for One, Jeanne Coret, Landreth Stringless, Lei de Linas, Masterpiece, Nain Crayon, Nogul, Pencil Pod Wax, Perfection, Soissons Main Patel, Soissons Mainee Gros Pencil, Staley's Surprise, Surecrop Wax, Susses R. Main, Sydney Wonder, Wagnaar, Stringless, Wellington Wonder.

CONTROL MEASURES

Bean refuse from an infected crop should be either destroyed by burning, or completely buried in the soil. Stakes from an infected crop should be disinfected by immersing either in 8% copper sulphate or lime sulphur 1–10. Preliminary tests have shown that lime sulphur 1–150 plus colloidal sulphur 2 lb.–100 gal. is effective in controlling rust. On late crops where infection is likely to occur, applications should be made when plants have become established, and repeated every 10 to 14 days. Three or four applications may be necessary according to severity of infection.

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PRELIMINARY NOTE ON THE EXTRACTION OF A BLOAT-PROMOTING FRACTION FROM RED CLOVER

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(Received for publication, 27 May 1954)

The numerous theories on the cause of bloat in ruminants are well reviewed by Cole *et al.* (1945) and by Dougherty (1953). A great deal of research has been directed towards finding a physiological explanation, but it is felt that the most promising approach to the problem is through an exhaustive examination of bloat-promoting pastures themselves, and that the immediate question is why, rather than how, certain pastures produce bloat when ingested by ruminants.

An investigation based solely on the fact that the ultimate source of bloat must lie in the materials ingested, and requiring no assumptions concerning the chemical nature of the possible causative component or components or of the mechanism which operates within the animal, was started in October, 1952.

The design of the investigation is one of progressive fractionation of the plant material with the use of test animals to locate the bloat-promoting fraction. The present note is a summary of the results obtained up to the end of 1953[2].

In the 1952 season (October-November) preliminary work was undertaken to determine the most suitable pasture species with which to work. In spite of the difficulties introduced by the use of such large animals, cows which were known to bloat readily in the field were used, since they are the most sensitive test animals available for this work. Although dry cows are considered to be less susceptible to bloat than are milking cows they were found to be satisfactory test animals and were used throughout the work reported here[3]. First it was shown that pastures which produced bloat when grazed would also produce bloat when cut and stall fed to the selected animals. The normal procedure was to starve the animals partially or completely overnight and to stall feed them with cut material for a maximum period of two hours starting at about 9 a.m. They were not fed again until about 1.30 p.m. by which time animals which had bloated at the morning feed had completely recovered. In this way, given suitable plant material, the animals could be induced to bloat twice per day.

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[2] When the author left for his present appointment.

[3] The author is grateful to A. Johnston, former Dairy Farm Manager, Massey College, for providing the ten test animals used in the first season, and to Dr. C. P. McMeekan, Superintendent, Ruakura Animal Research Station, for donating the three sets of identical twins used in the second season.

The preliminary work indicated that red clover was the most suitable material for the proposed investigation, since its bloat-producing ability when developed was high and was retained to a greater or less degree for several weeks; it was more palatable than white clover when cut and stall fed and, probably because of this, gave more consistent results than did white clover; and, unlike white clover, it contains no cyanogenetic glucoside which has been claimed as a positive agent in producing bloat (Evans and Evans, 1949) and which, in sufficient dosage, can give rise to cyanide poisoning. The whole of the red clover plant, cut 1-2 in. above the ground, was used since no localisation of the activity to the upper or lower half of the plant could be demonstrated and the stems were shown to be comparable in activity to the leaves and petioles. It was also established that the activity was not lost during storage of freshly cut material at $-10°$C. for three days.

Of the grasses, only perennial and short-rotation ryegrasses were tested and, although cut at different stages of development and from different manurial treatments, these species at no time throughout the 1952 season produced bloat in the test animals. This work was not sufficiently exhaustive or critical to allow the conclusion that these species are never responsible for the production of bloat, but it does support the conclusion of other workers (see reviews cited above) that, compared with certain pasture legumes, grasses are relatively "safe".

During the 1953 season, which comprised only a few weeks in November-December, work was commenced on fractionation of red clover. A note by Parsons *et al.* (1952) on the production of bloat in sheep following the administration of extracts of ladino clover and lucerne had appeared before any of the fractionation work described below could be carried out, but since

their published information did not define the nature of their extract an independent procedure for the initial fractionation step had still to be investigated.

Material which was known from feeding tests to produce bloat was stored at —10°C. until completely frozen or longer, thawed rapidly, and the vacuolar liquid expelled in a large hydraulic press. From 80 lb. of red clover treated in this way, about 35 lb. of juice was obtained, and no attempt was made to remove the remainder of the vacuolar contents by washing the press cake.

The fractions were tested immediately after separation except when required for morning use when they were prepared the previous afternoon and stored at 3°C. overnight. Liquids were administered by drenching (16 - 18 l. being the normal individual dose) and after ingestion of the press cake when the combined effect of press cake and a liquid was tested. Glucose was added to some of the test feeds which did not include juice to assure the presence in the rumen during the test of a readily fermentable substrate.

The criterion for bloat was marked, reasonably firm distension of the rumen which persisted for at least 60 min. It was found that, of the feeds tested, only those which included press juice (i.e., juice alone or juice with press cake) ever fulfilled these requirements. The production of a slight but persistent puffiness of the flank was considered to be an inconclusive result. No persistent symptoms of bloat were observed with any of the following: water; 3 per cent glucose solution; press cake alone; press cake with powdered glucose added in excess of the amount of total reducing sugar (after hydrolysis) removed in the press juice; press cake with water; and press cake with 3 per cent glucose solution. Occasionally it was noted that animals drenched with glucose solution or with press juice appeared to be bloated before or immediately after the drenching operation was concluded, but this condition was of short duration and the symptoms had completely disappeared within ten minutes. Such cases were recorded as negative.

Of the first ten tests using juice alone, four were positive, two were inconclusive and four were negative. Two of these ten evaluations were made in the morning, i.e. after overnight starvation, and one of these produced a positive response. Since the test animals were not consistent in their bloating behaviour, even when fed fresh material which was known to be potent, variable results were not unexpected. It is, however, possible that there would have been more positive responses to a higher dosage since negative results were obtained in three tests using only 9.1 of juice, while, on the only occasion when this was tried, a negative response to 16 l. of juice was changed to a positive response when a further 8 l. was administered.

It is hard to reconcile the results of the feeding tests reported here with any theory that regards bloat as being due solely to a lack of coarse material in the feed.

This work was concluded before the publication of Lindahl *et al.* (1954) of their results on the production of bloat on a juice derived from ladino clover or lucerne and by a crude saponin fraction from lucerne, and before a further report by Parsons *et al.* (1953) became available. The results described in the present paper support the conclusions of both these groups and of Ferguson (1953) that the cause of bloat should be sought in the non-fibrous part of the herbage. The extent to which constituents, either of the cytoplasm or of the cell wall, assist in the production of bloat cannot be determined from the work published thus far, but there is now strong evidence that the compound or compounds basically responsible for the condition are in solution in the vacuolar liquid.

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NOTE ON VARIATIONS IN THE UDDERS OF MONOZYGOTIC CATTLE TWINS

By D. S. Flux, The Dairy Research Institute (N.Z.), Palmerston North

(Received for publication, 9 August 1954)

Cases of udder or teat abnormalities in monozygotic twins are of interest because of the indications which they may give of the genetic basis for differences in mammary gland or teat structure.

Relative Yields of Front and Rear Quarters of the Udder

In six pairs of monozygotic twin heifers the milk yields of the four quarters of the udder were measured separately on four occasions during lactation. Large and statistically significant differences existed between twin pairs in the relative milk yields of the front and rear quarters. These differences ranged from 35.7% of the total milk from the front and 64.3% from the rear quarters in one pair of twins to 55.6% from the front and 43.4% from the rear quarters in another pair. Differences between cows of the Jersey and Friesian breeds in this respect have been shown to exist, (an average of 44.4% of the total milk yield was obtained from the front and 55.6% from the rear quarters in 38 Jersey cows and 38.0% from the front and 62.0% from the rear quarters in 26 Friesians), but cows that yield more from the front than the rear quarters appear to be unusual. The yields of the two front quarters and the two rear quarters were compared in both the twins and ordinary cows and no significant differences between the producing capacities of the left and right sections of the udder were found.

Blind Quarters

One pair of monozygotic twins in which one sister gave no milk from one front teat and the other sister none from either front teat was collected by the Dairy Research Institute (N.Z.). Both had four teats which appeared normal on casual examination. In late pregnancy it was noticed that the udders were not symmetrical, and when milking started it was found that no milk could be drawn from some teats. After slaughter it was found that the teats that gave no milk had small teat sinuses which ended as blind sacs at the level of the point of attachment of the teat to the udder. Although there was mammary gland tissue above these teats they were not connected to it. The larger milk ducts could be traced to the gland cistern of the rear quarter on the same side of the udder in each case. Unfortunately the twin sisters had been subjected to different nutritional treatments before calving and although their milk yields were very similar they may have been affected by the previous treatment.

The teat cistern, gland cistern, and mammary duct system of each quarter are believed to develop by inward growth of the primary sprout of the teat (Turner, 1952). It appears therefore that in these twins the growth of some of the primary sprouts stopped at a very early stage. The fact that it occurred in both members of the pair suggests that the abnormality has a genetic basis, but apparently the degree of expression of the effect was variable.

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INSECTICIDES AND COLONIAL AGRICULTURAL DEVELOPMENT. *Ed.* by T. Wallace and J. T. Martin. Butterworths Scientific Publications. 1954. 169 pp. 30s.

This publication comprises the Proceedings of the Sixth Symposium of the Colston Research Society held in the University of Bristol, 23–27 March 1953. The Symposium consists of an Introductory paper on the Importance of Crop Protection to the Colonies and its Relation to Agricultural Development, and fifteen papers dealing with the problems involved in the control of the major insect pests in the Colonies.

PROCEEDINGS OF THE BIHAR ACADEMY OF AGRICULTURAL SCIENCES. Vols. II and III. 1953–54. 156 pp.

This official publication of Bihar Academy is in future to be issued annually. A number of the eleven papers should be of interest to Agricultural Research workers in New Zealand. It includes articles on Improvement of Soil Fertility by the Application of Heat, New Systems for the Maintenance of Soil Fertility and the Effects of Insecticides on Aphids and their Parasites and Predators.

THE JOURNAL OF SOIL SCIENCE. Vol. 5 No. 1. Jan. 1954. Oxford at Clarendon Press. 172 pp.

This issue of the Journal of Soil Science maintains the high standard set in the previous volumes. It includes a series of three articles on Podzolization, and articles on Release of Silica from Soils by the Orthophosphate Anion, Soil Structure in Relation to Soil Suction, Isotropic Equilibria between Phosphates in Soil, etc.

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